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Chikamoto

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(54) **INKJET HEAD, FILTER PLATE FOR INKJET HEAD, AND METHOD OF MANUFACTURING FILTER PLATE**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
B41J 2/175 (2006.01)

(52) **U.S. Cl.** **347/93**

(58) **Field of Classification Search** None
See application file for complete search history.

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(57) **ABSTRACT**

An ink channel is formed in an inkjet head, so that ink introduced through an ink inlet passes through a pressure chamber and is ejected out of a nozzle. A filter for filtering the ink is disposed in the ink channel. The filter includes a depression formed in a plate, and a plurality of through-holes formed in the bottom of the depression. The filter has small channel resistance and is easy to handle.

23 Claims, 12 Drawing Sheets

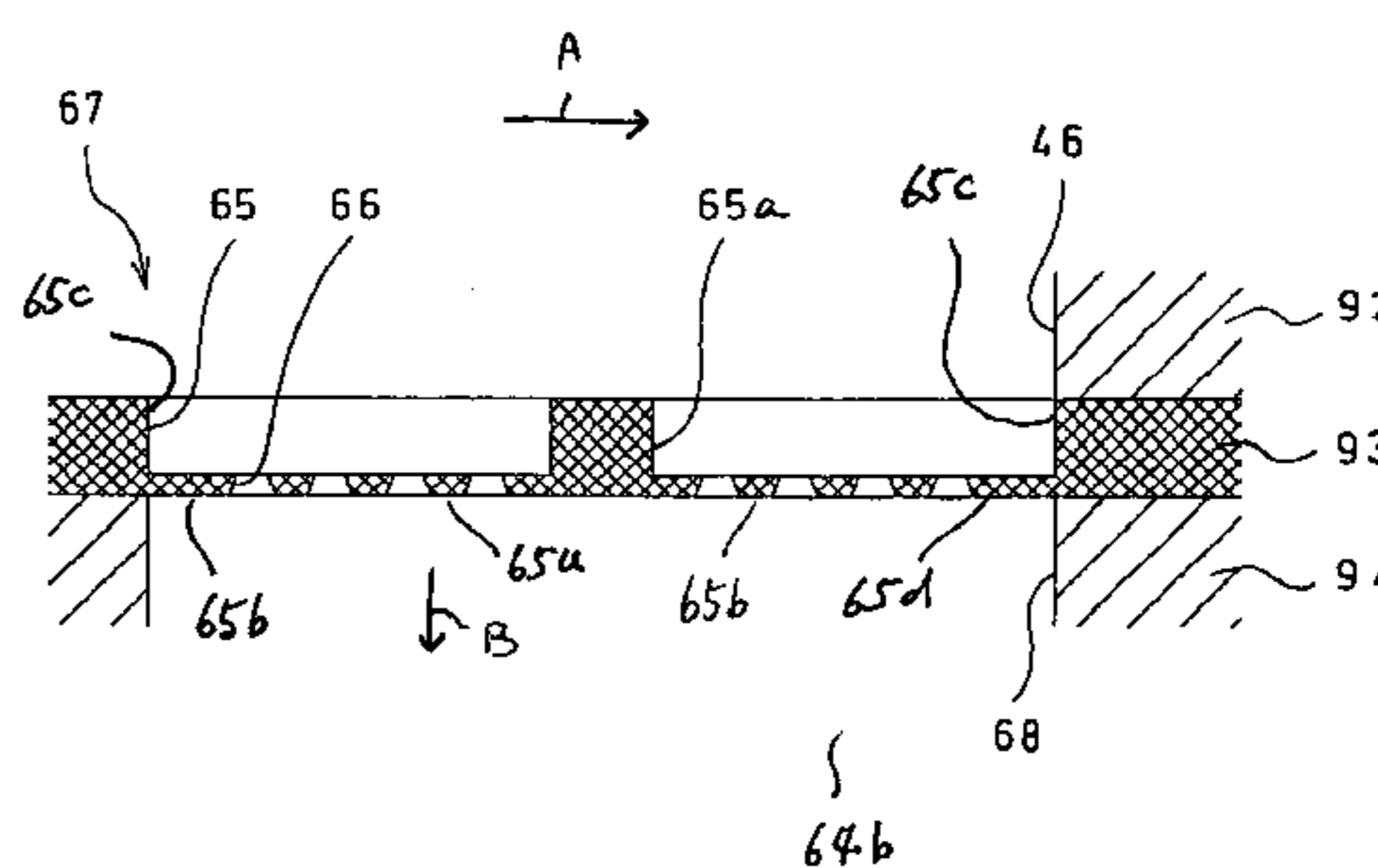
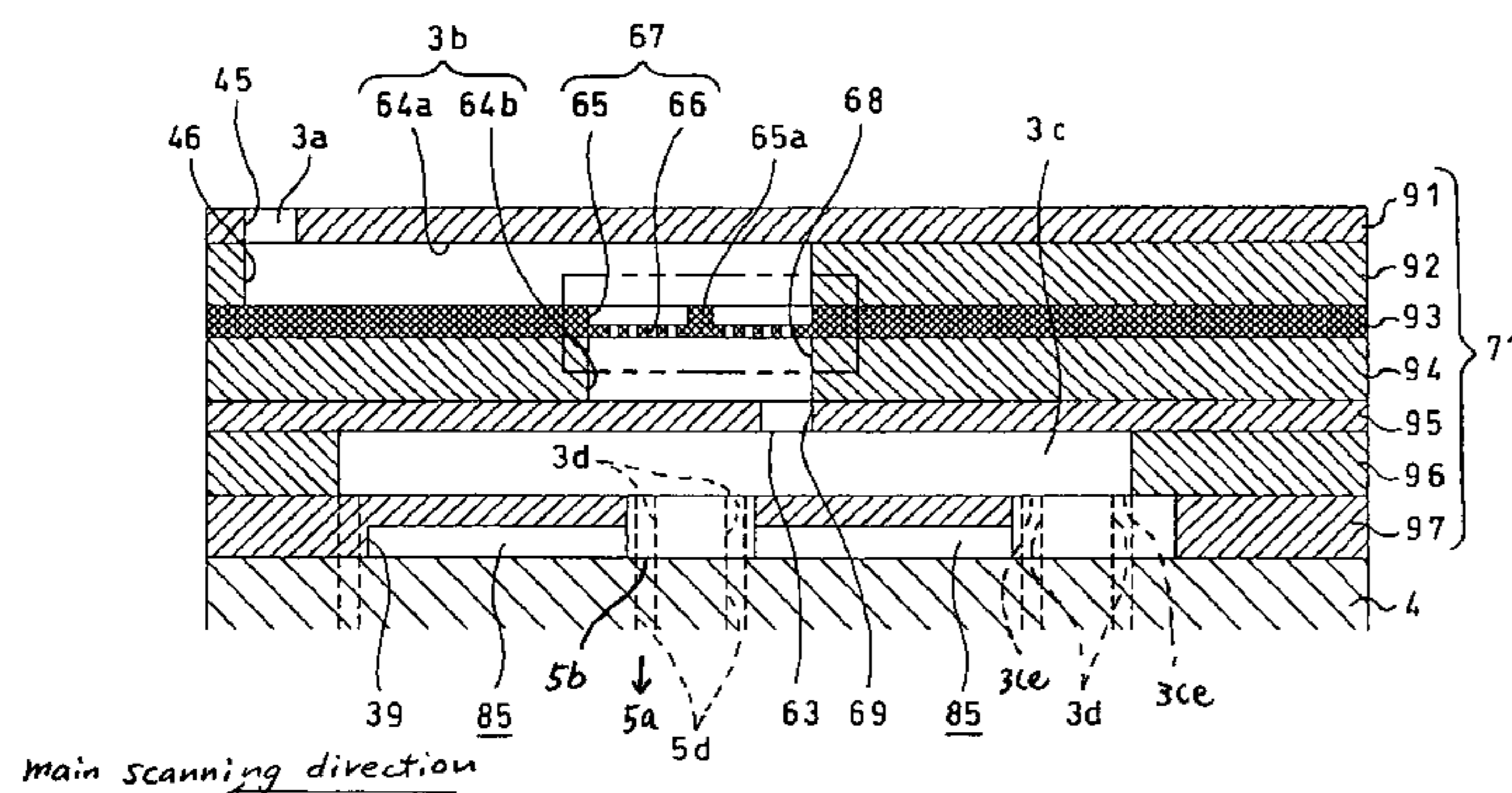


FIG. 1

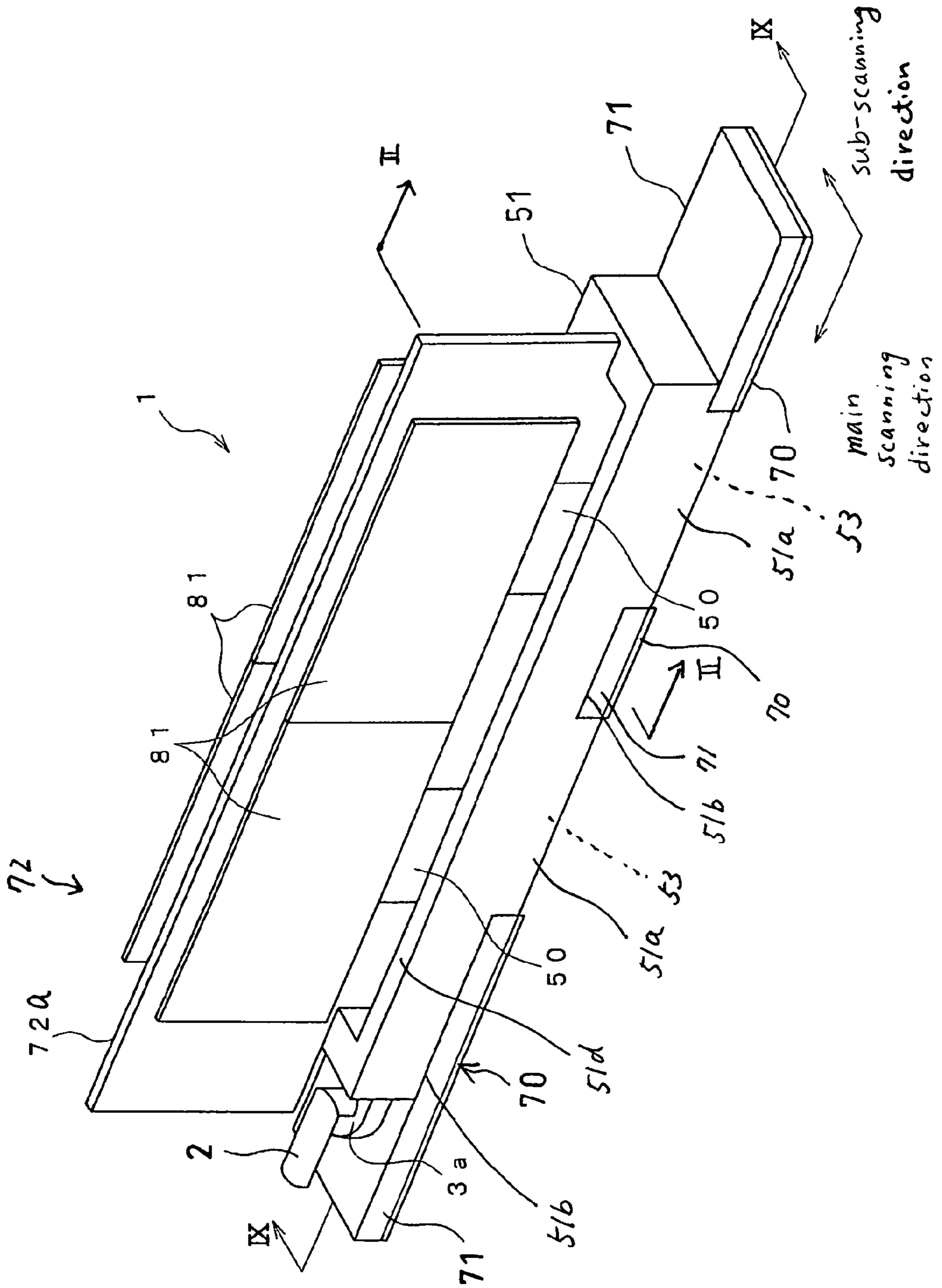
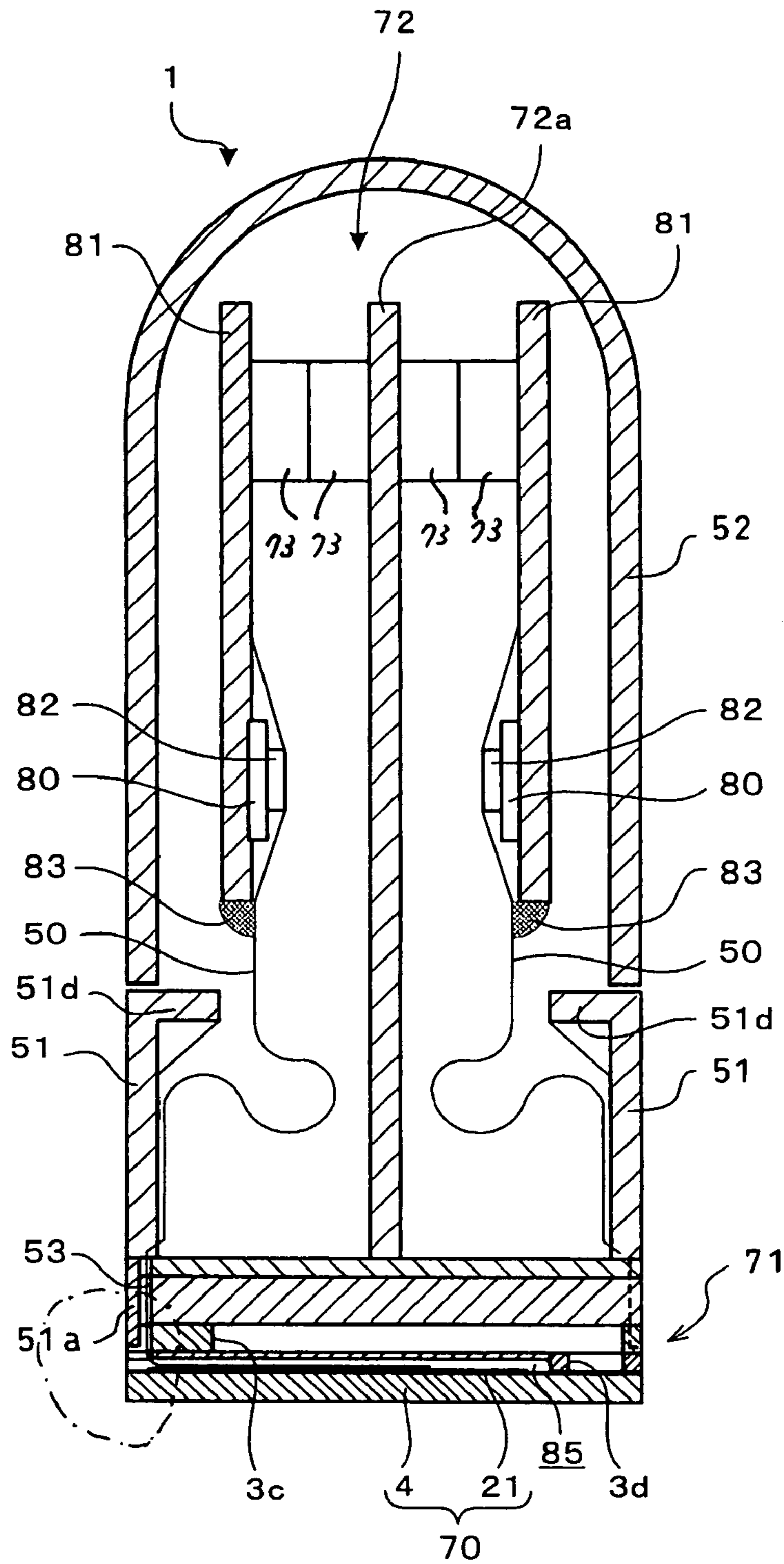


FIG. 2



←
sub-scanning direction

FIG. 3

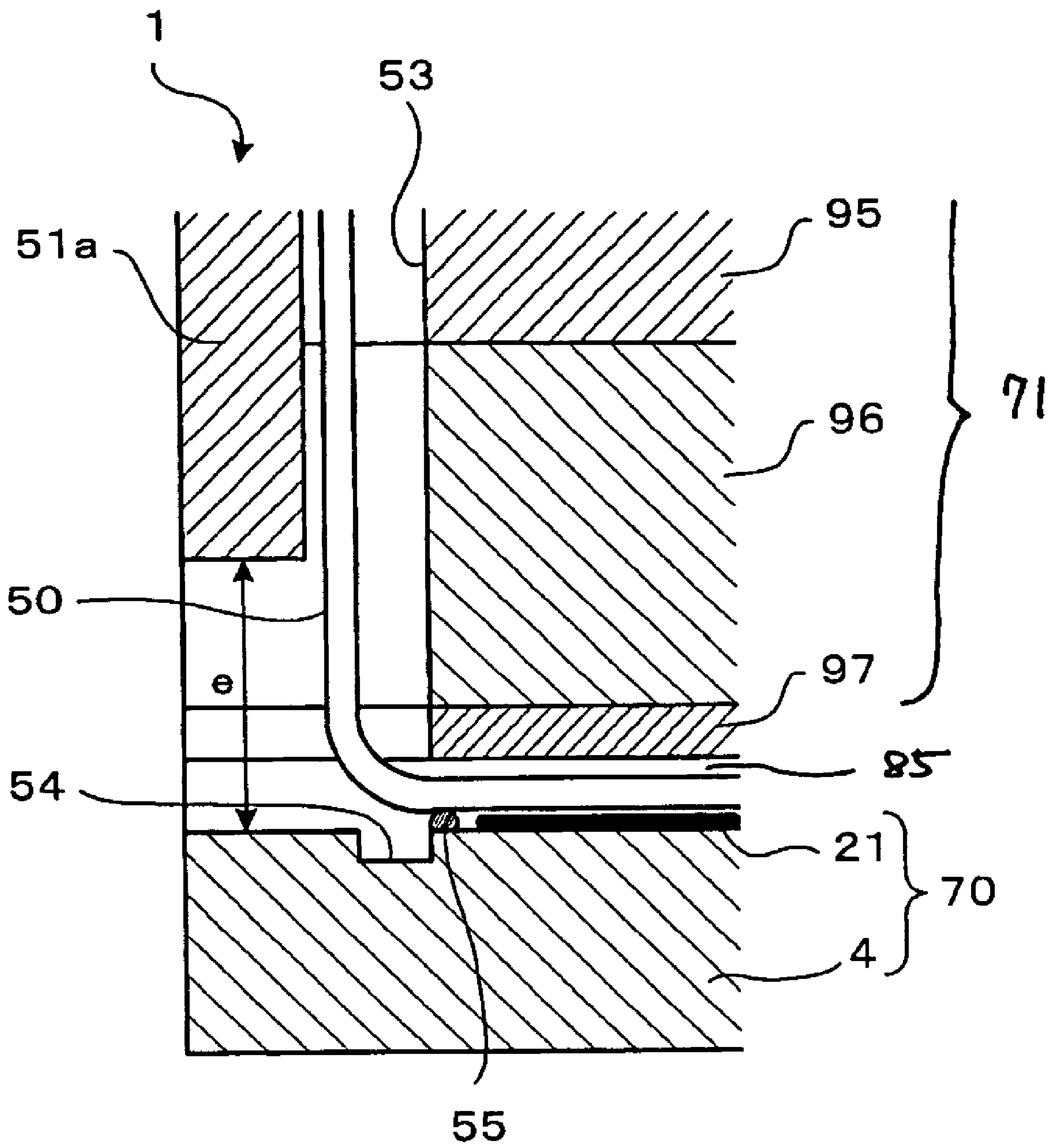


FIG. 4

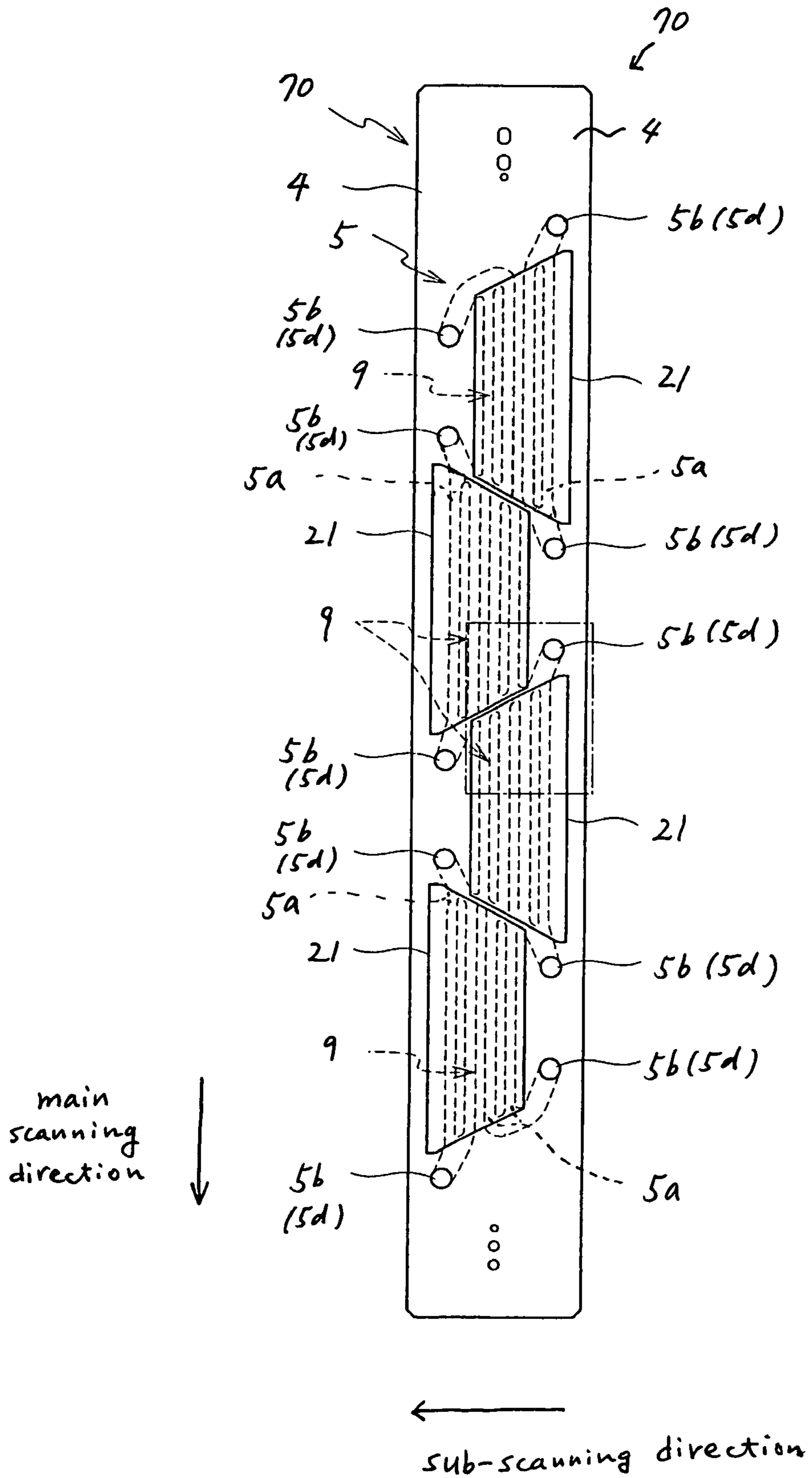


FIG. 5

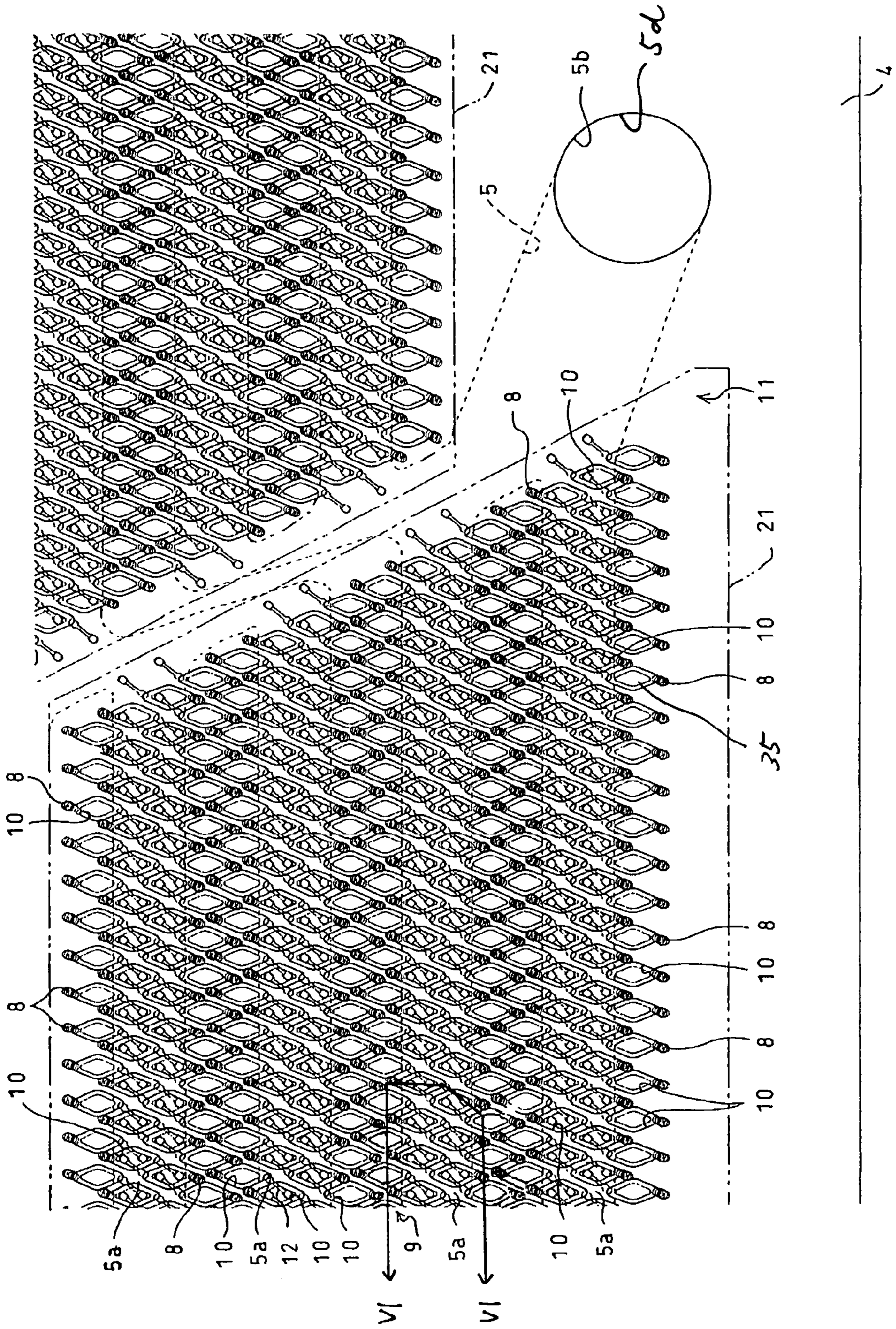


FIG. 6(a)

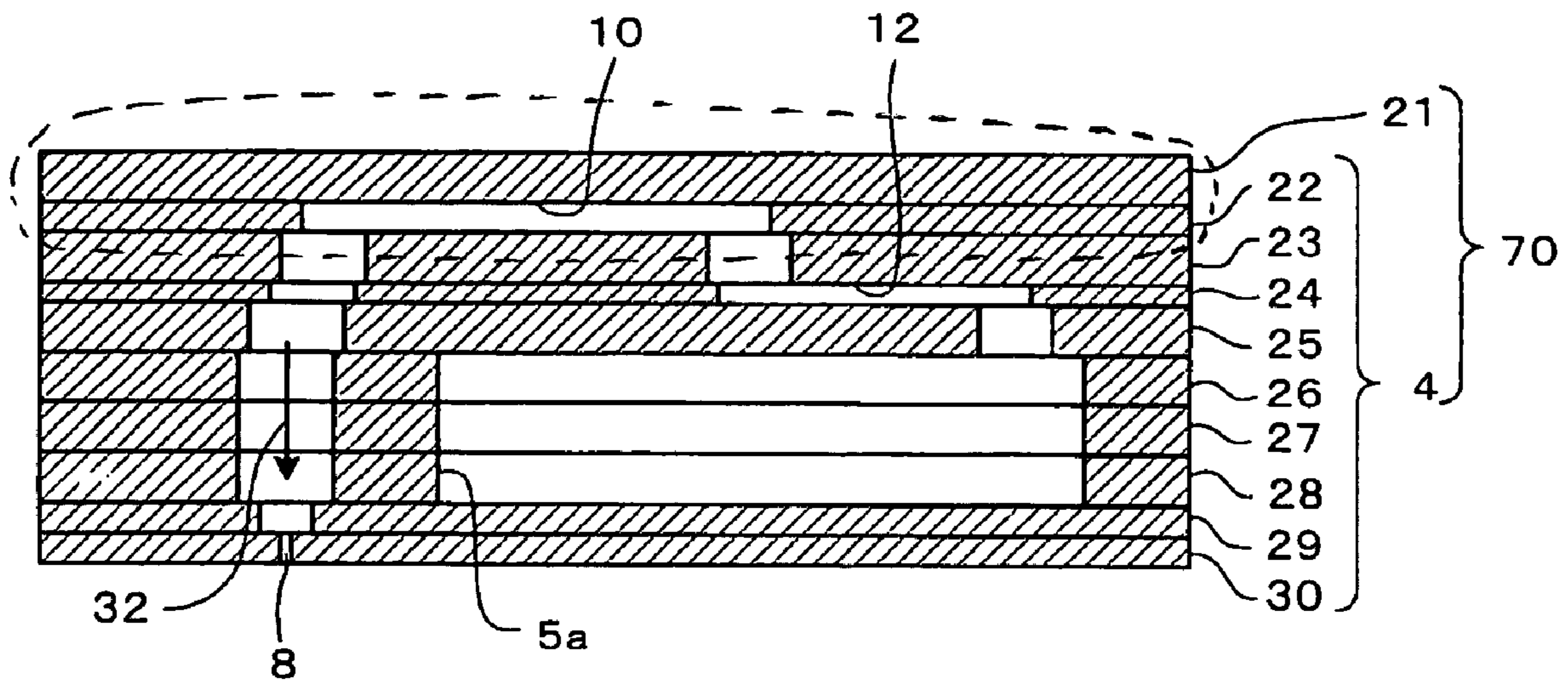


FIG. 6(b)

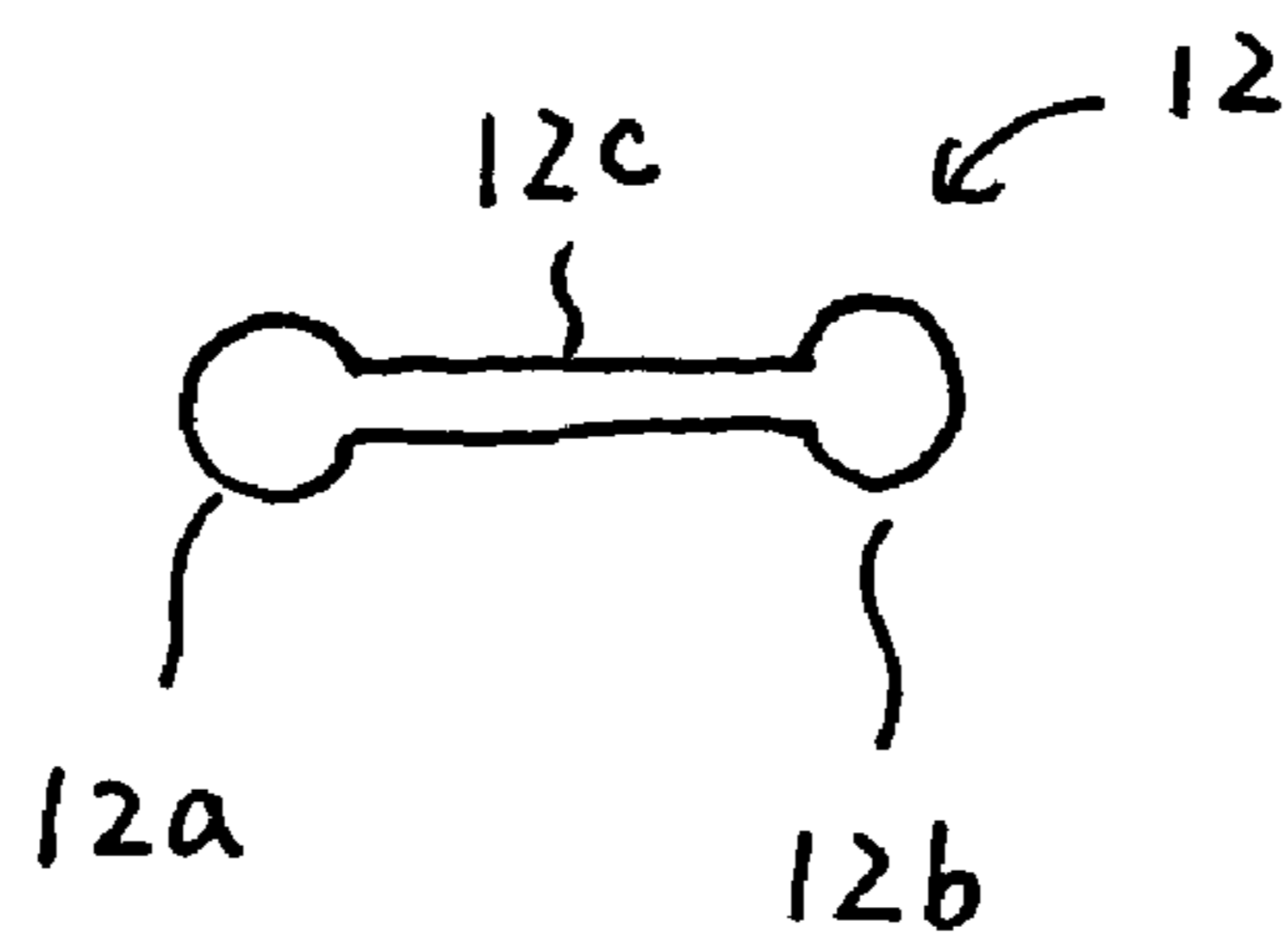


FIG. 7

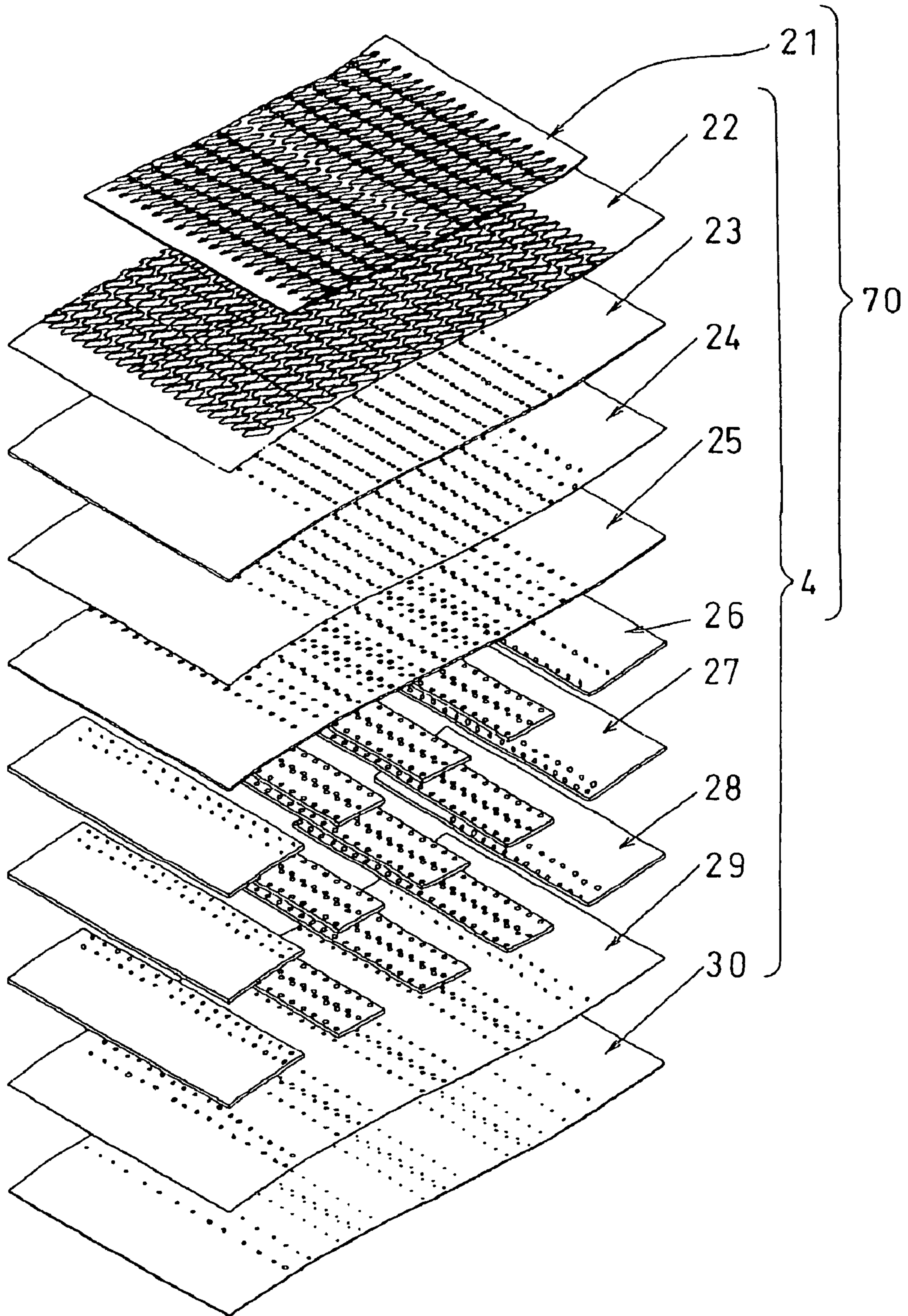


FIG. 8(a)

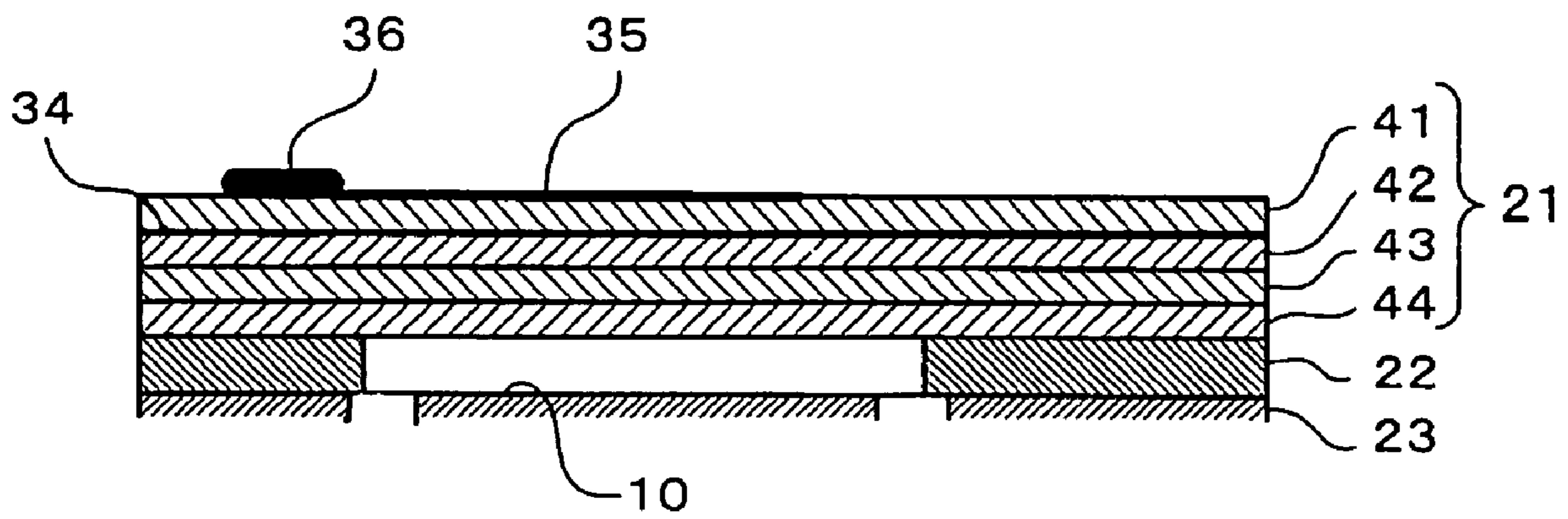


FIG. 8(b)

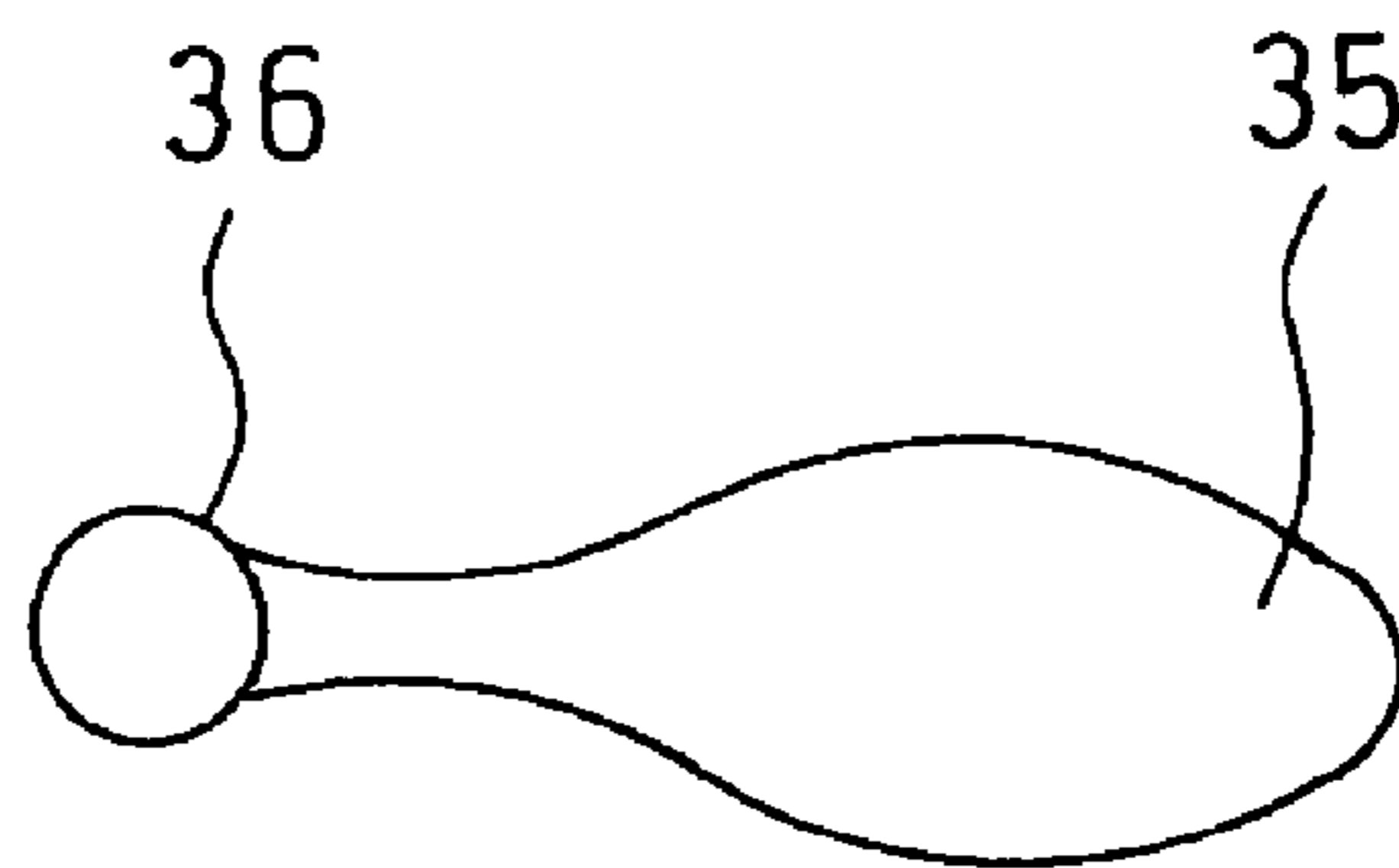


FIG. 9 (a)

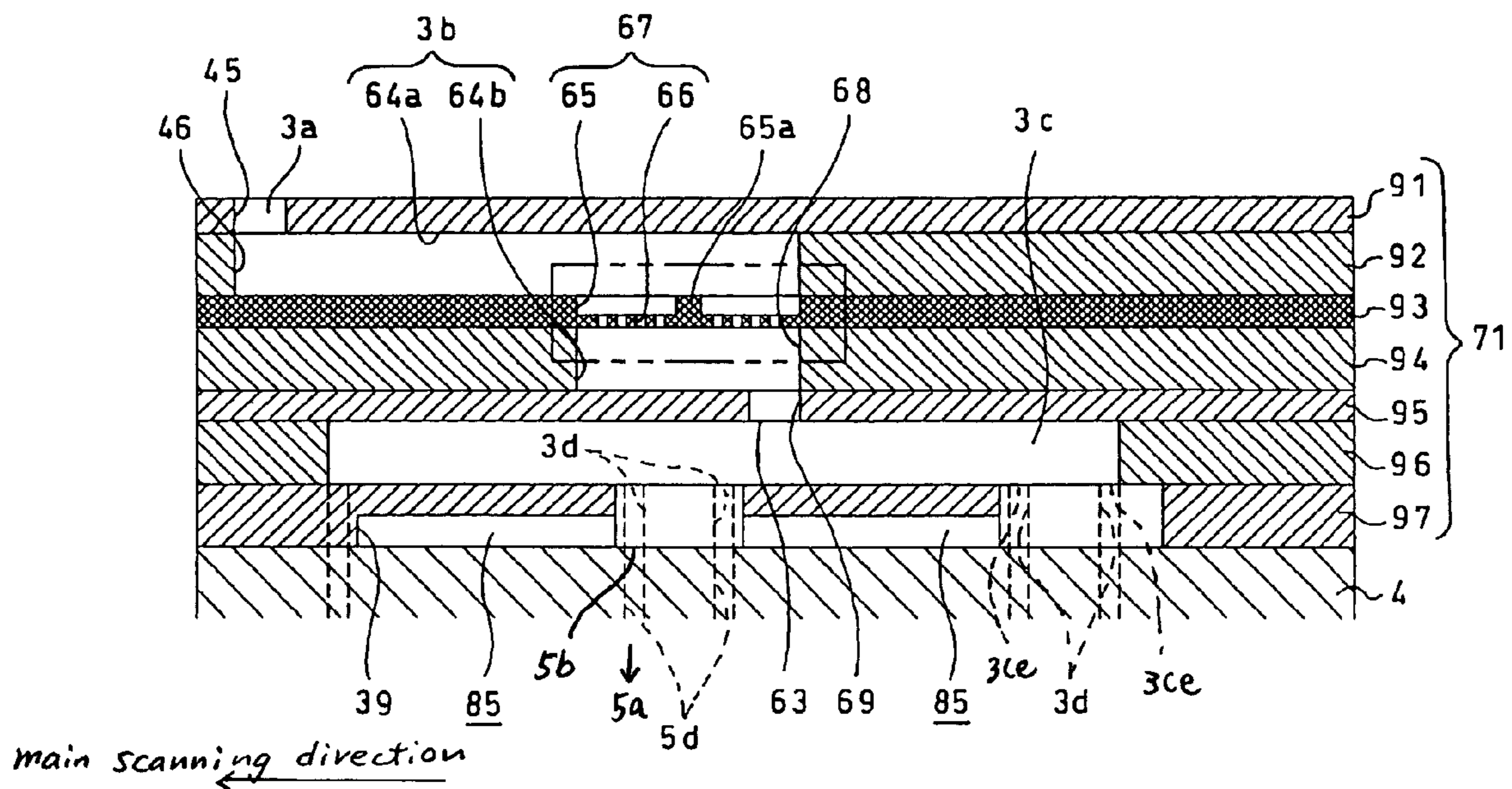


FIG. 9 (b)

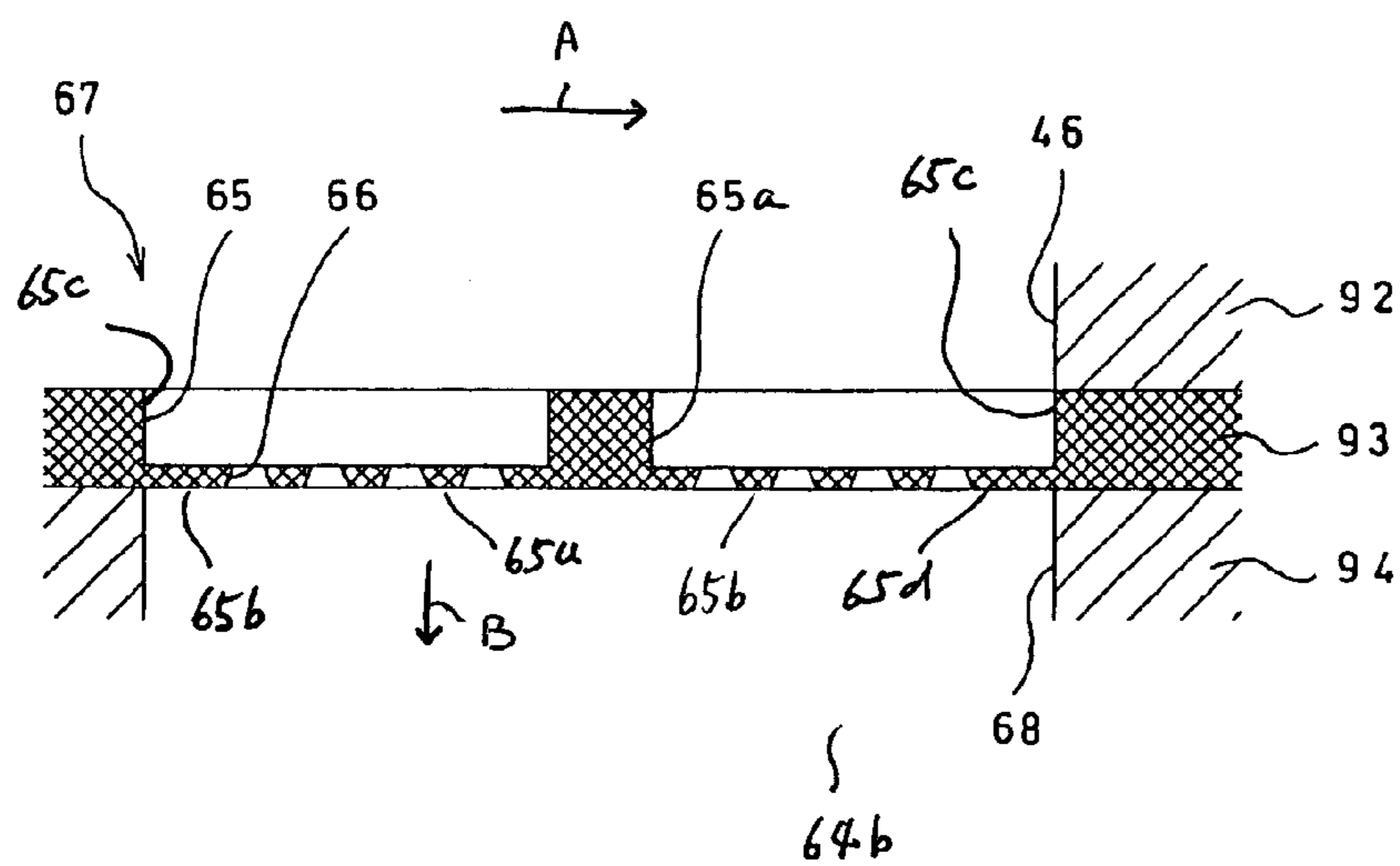


FIG. 10

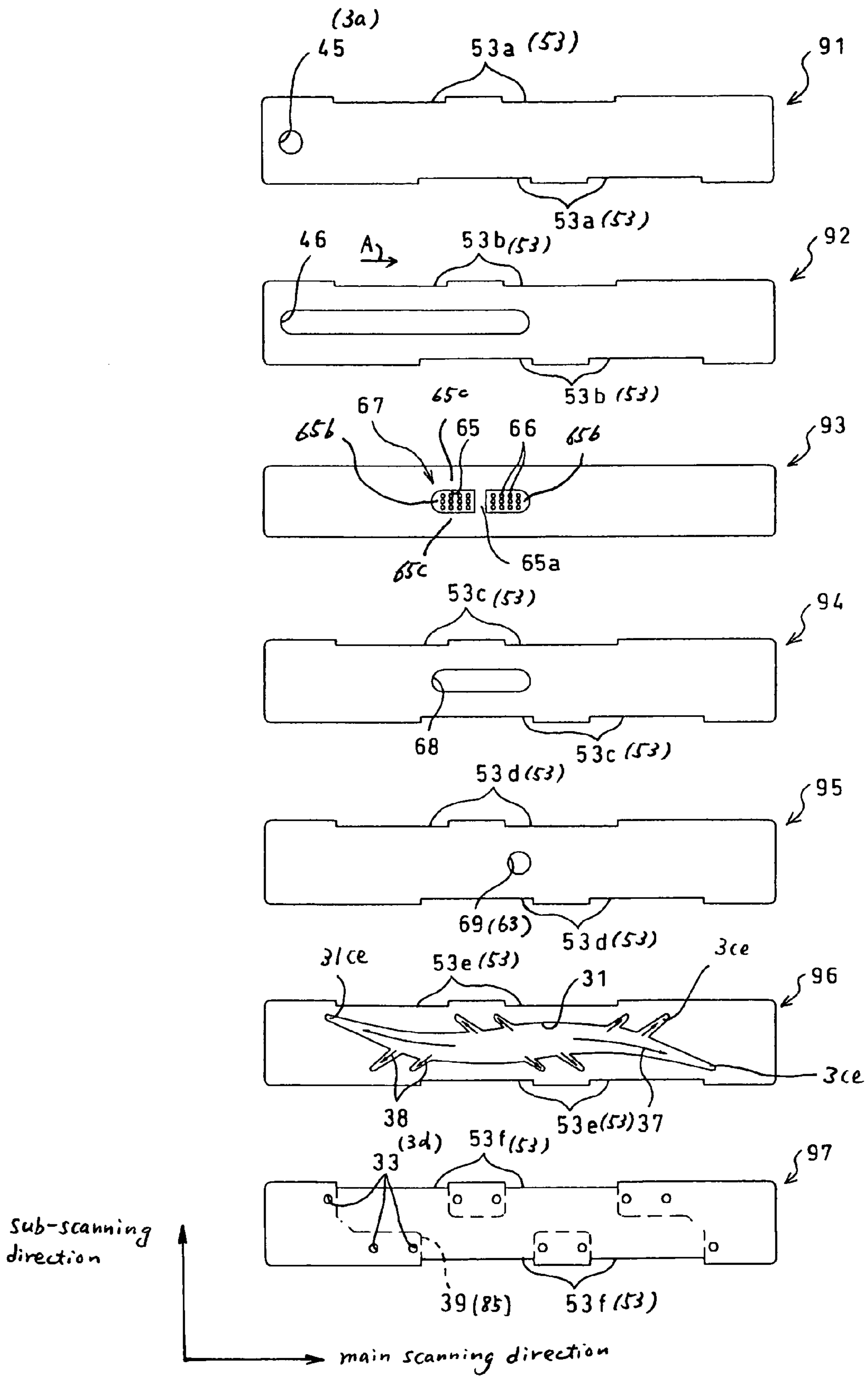


FIG. 11(a)

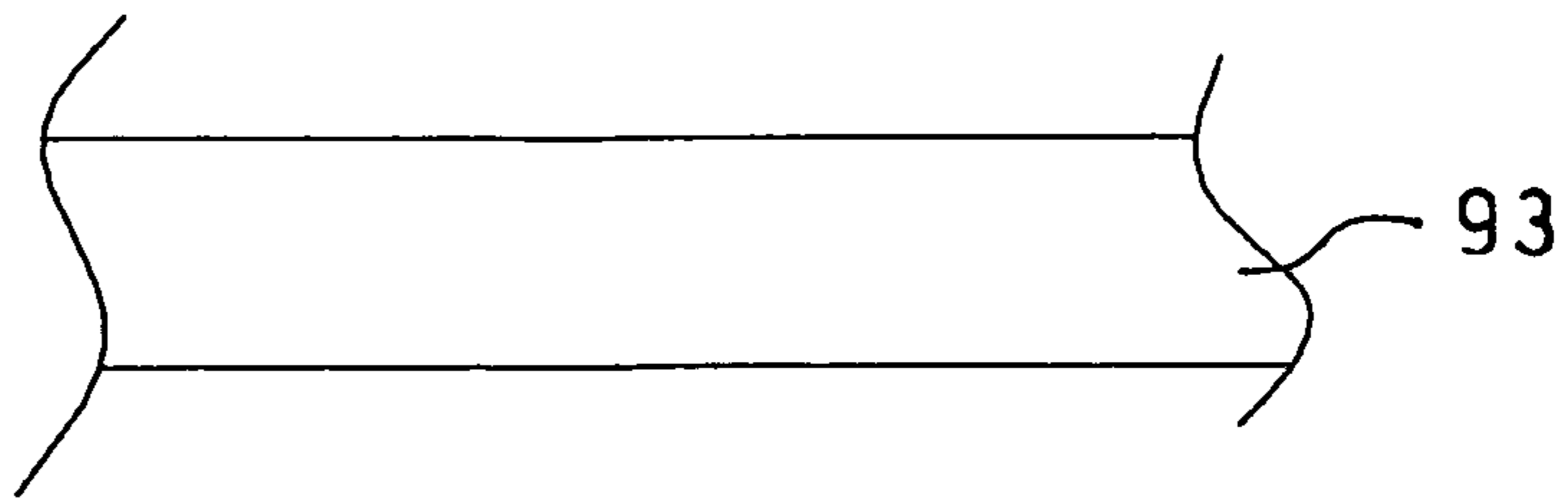


FIG. 11(b)

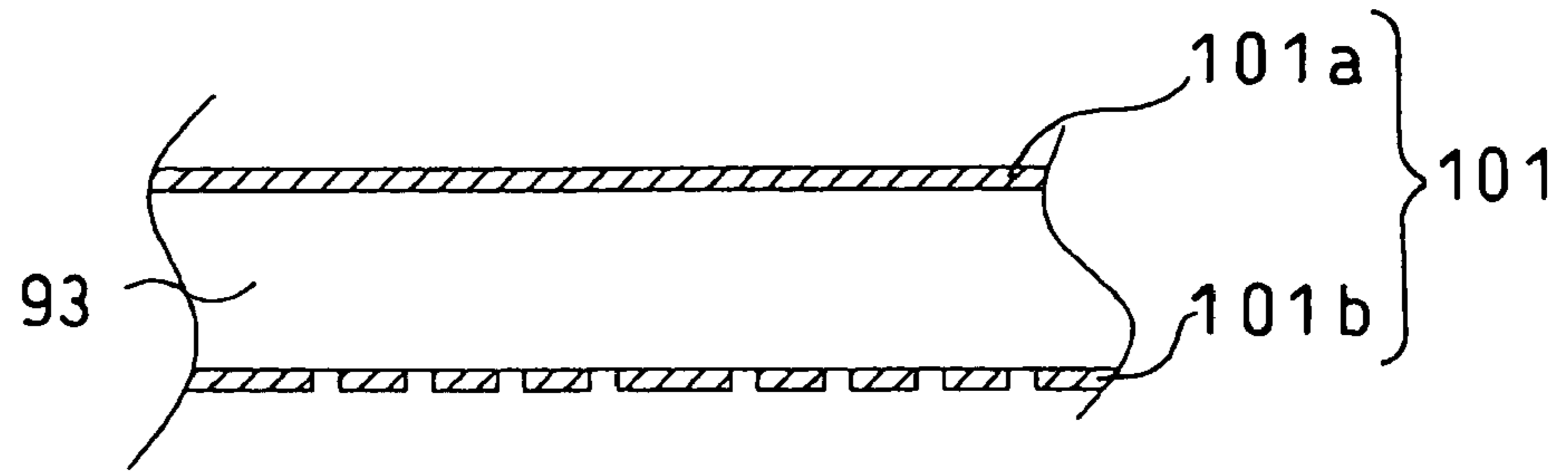


FIG. 11(c)

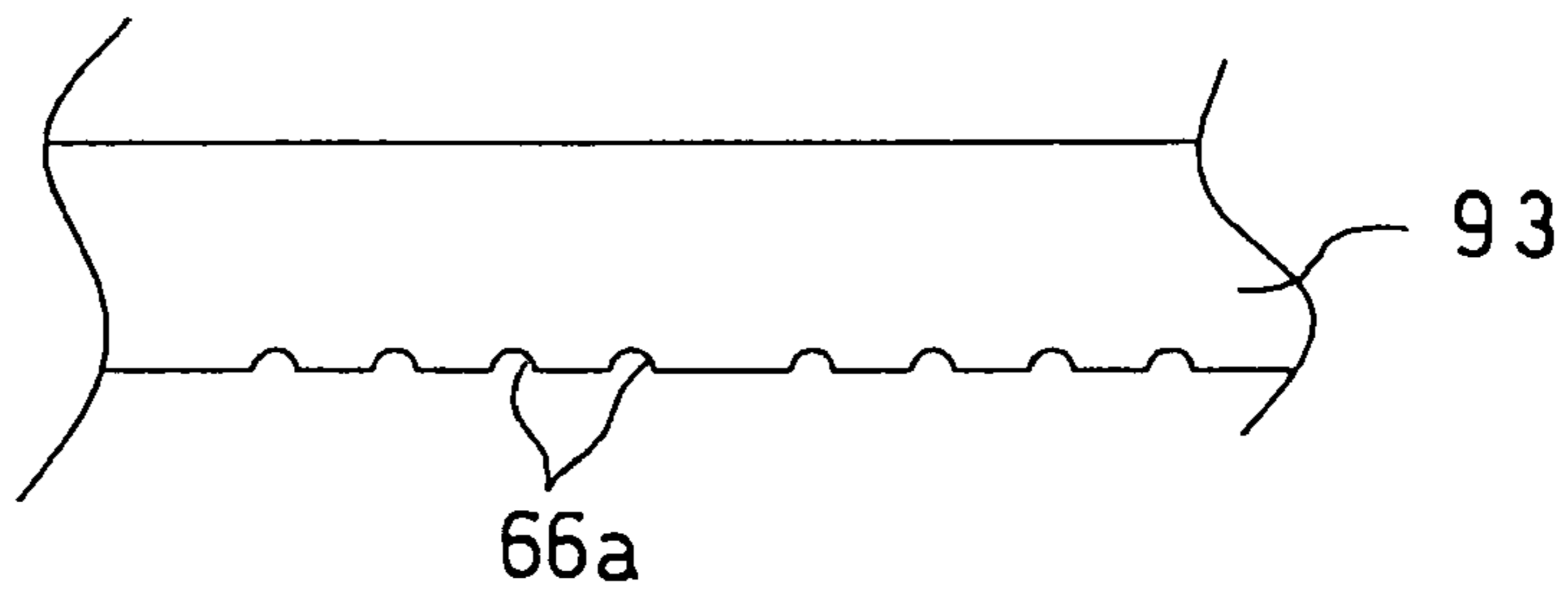


FIG. 11(d)

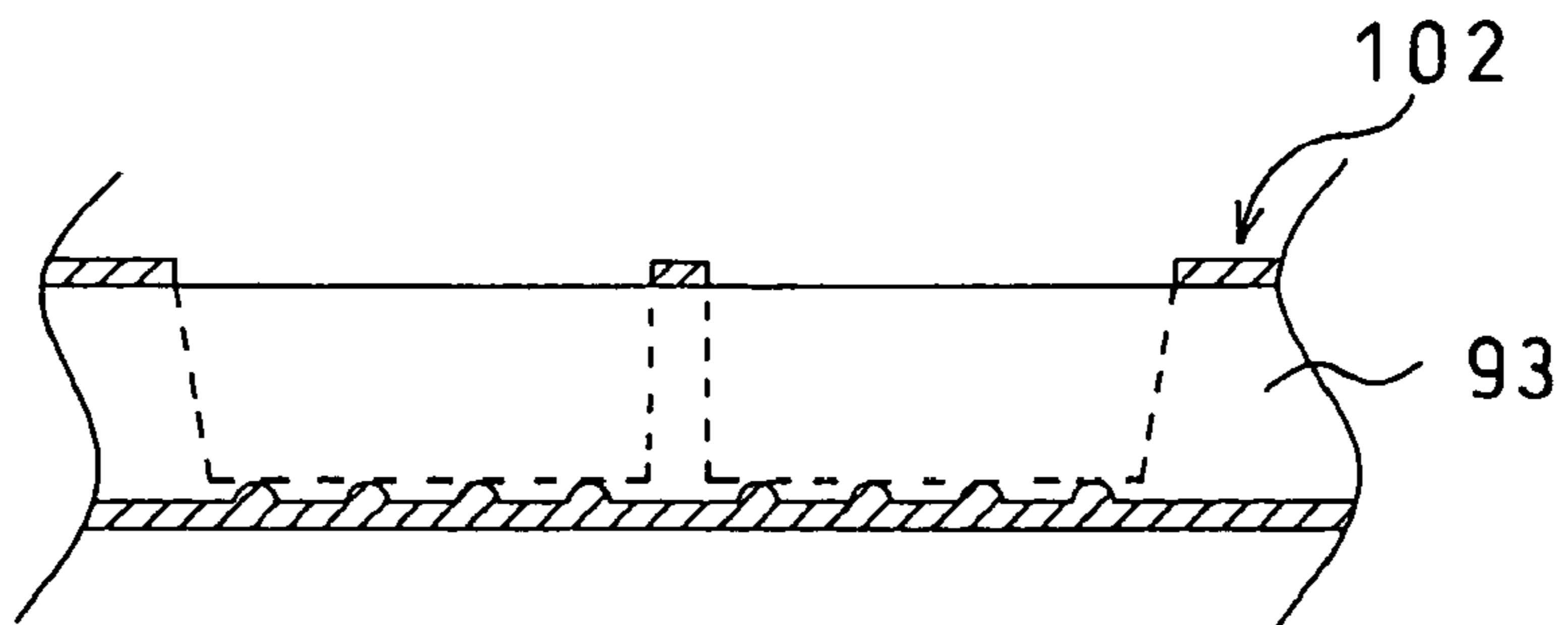


FIG. 11(e)

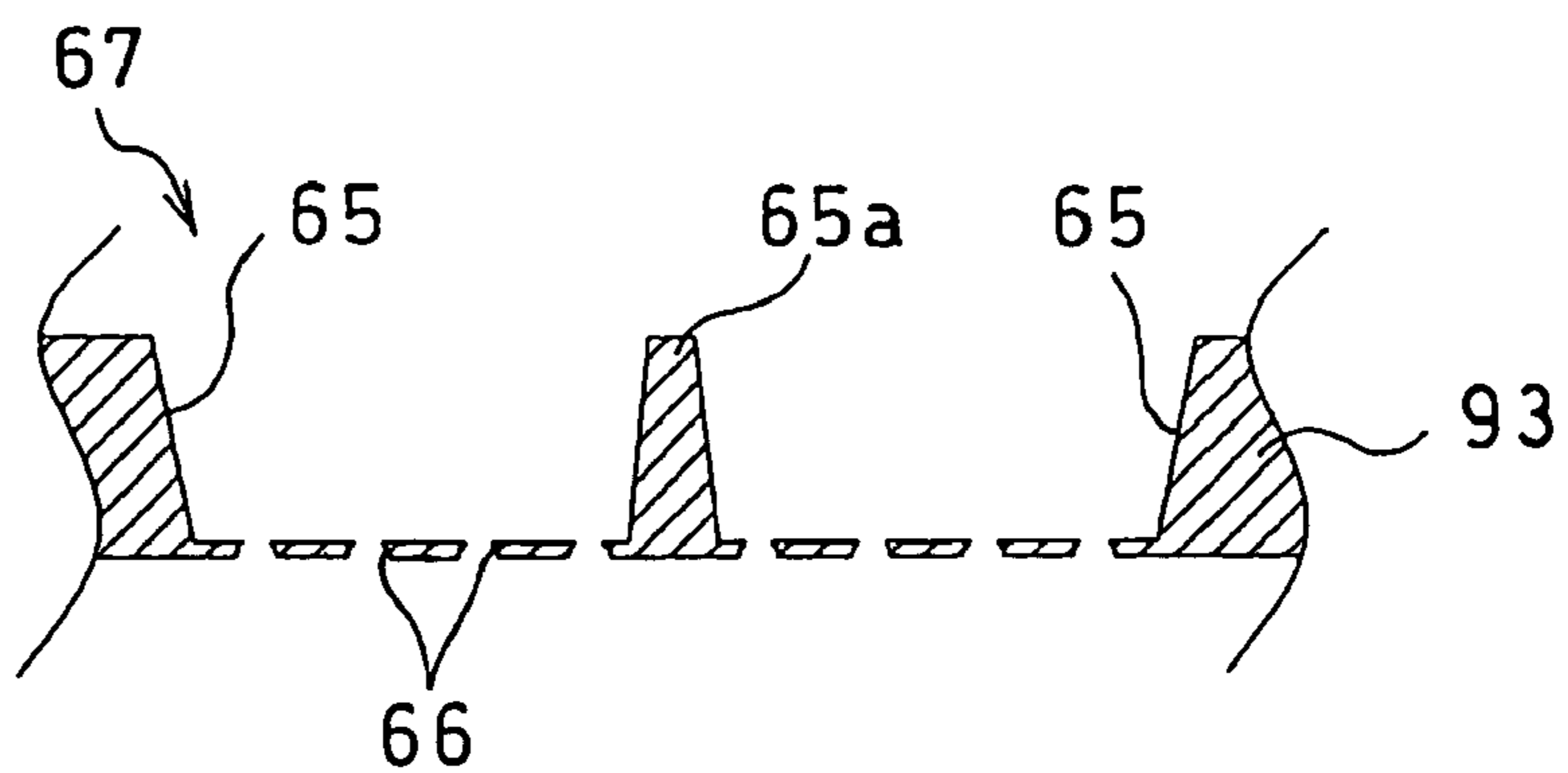


FIG. 12(a)

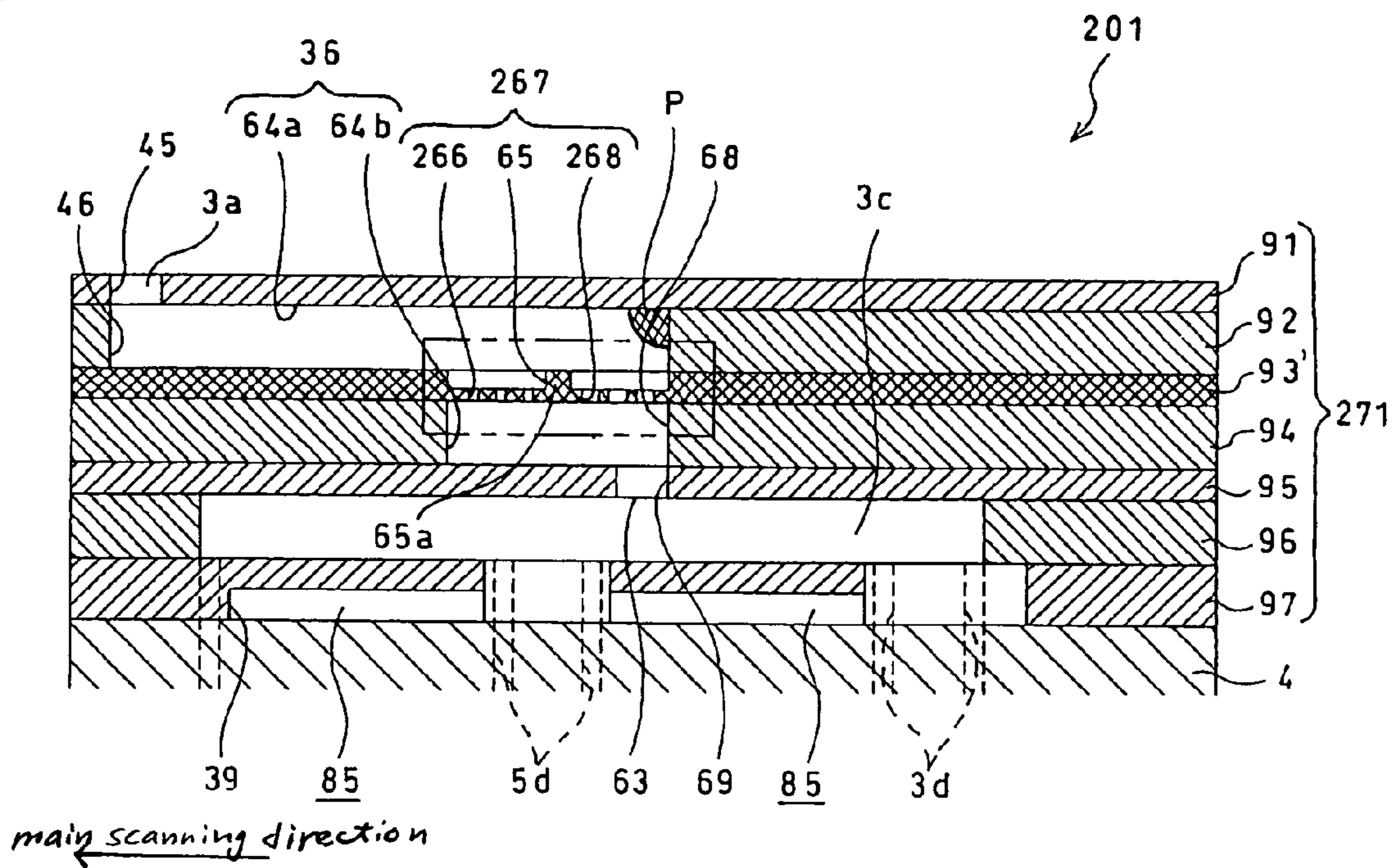
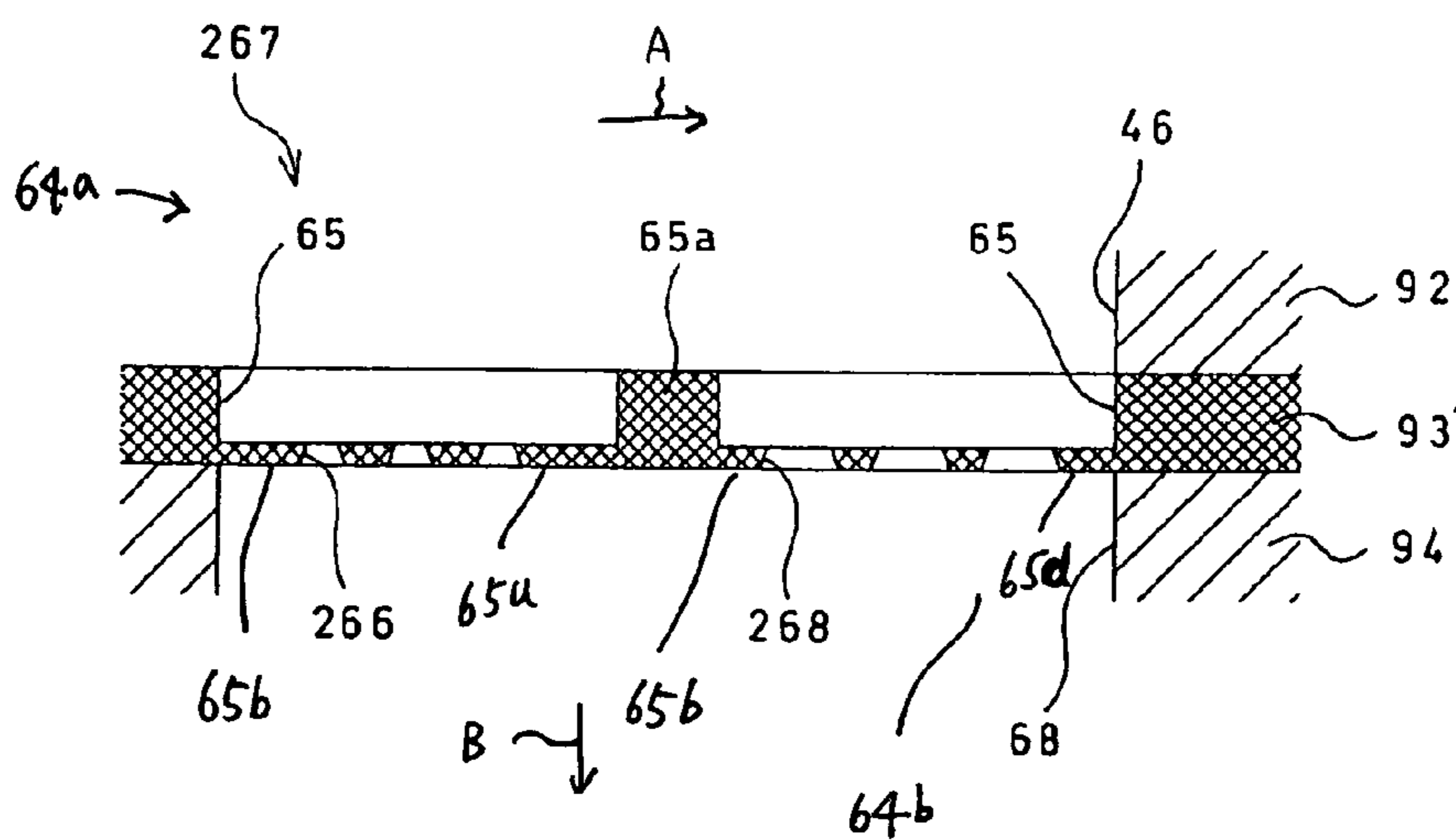


FIG. 12(b)



INKJET HEAD, FILTER PLATE FOR INKJET HEAD, AND METHOD OF MANUFACTURING FILTER PLATE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an inkjet head for performing a printing operation by ejecting ink onto a recording medium; a filter plate for an inkjet head having a filter for trapping foreign matter in the ink; and a method for manufacturing the filter plate.

2. Description of Related Art

Japanese unexamined patent application publication No. HEI-6-255101 discloses an inkjet head configured of laminated channel plates and having nozzles for ejecting ink, ink pressure chambers for applying pressure to the ink, a common ink chamber for distributing ink to each of the ink pressure chambers, and a supply channel for supplying ink from an ink tank to the common ink chamber. In this inkjet head, a filter having a plurality of through-holes formed by etching or the like is disposed between the common ink chamber and the supply channel. Accordingly, foreign matter in ink supplied from the ink tank can be trapped by the filter so that the matter does not enter the common ink chamber. Therefore, the inkjet head can prevent problems in ink ejection caused by foreign matter clogging the ink channel.

SUMMARY OF THE INVENTION

However, in the inkjet head disclosed in the document described above, the channel plate in which the filter is formed is extremely thin and weak and, therefore, must be handled delicately when stacked with the other channel plates, making the laminating process difficult.

To resolve this problem, it is conceivable to use a thicker channel plate. However, when forming filter through-holes in the channel plate by etching, for example, the diameter of the through-holes grows larger in proportion to the thickness of the plate, giving rise to a new problem of a filter having an insufficient capacity to trap foreign matter, which capacity determines the filtering characteristics.

When forming through-holes by etching, generally a resist layer having openings approximately the same diameter as the filter through-holes is coated on one surface of the channel plate, and the regions exposed in the openings are etched by a chemical solution. However, since the etching proceeds isotropically and not only in the thickness direction of the plate, by the time through-holes are formed penetrating a thick plate, the etching has proceeded also to the underside of the resist layer, resulting in through-holes with a large diameter.

Therefore, it is an object of the present invention to provide an inkjet head that improves the strength of the plate in which a filter portion is formed without a loss in filtering characteristics, making the plate easy to handle.

It is another object of the present invention to provide a filter plate that is strong and easy to handle, without a loss in filtering characteristics, and a method for manufacturing such a filter plate.

In order to attain the above and other objects, the present invention provides an inkjet head including a plurality of laminated plates. The plates have holes that are arranged in communication with one another to form an ink channel. At least one of the plurality of plates includes a filter portion disposed in the ink channel. The filter portion includes a

bottom wall portion defining a depression thereon. A plurality of filter through-holes are formed through the bottom wall portion.

According to another aspect, the present invention provides a filter plate for an inkjet head. The inkjet head includes a plurality of laminated plates. The plurality of plates include the filter plate. The plurality of laminated plates have holes that are arranged to form an ink channel. The filter plate includes a filter portion. The filter portion is disposed in the ink channel which is formed when the plurality of plates are laminated together. The filter portion includes a bottom wall portion defining a depression thereon. A plurality of filter through-holes are formed through the bottom wall portion.

According to another aspect, the present invention provides a method of manufacturing a filter plate serving as a component of an inkjet head including a plurality of laminated plates. The plates have holes that are arranged to form an ink channel. The filter plate has a filter portion that traps foreign matter in ink in the ink channel. The method includes: forming a plurality of holes within a predetermined region on one surface of a metal plate, the holes having a depth smaller than the thickness of the metal plate; and forming filter through-holes penetrating the metal plate by etching a depression across the entire predetermined region on the opposite surface of the metal plate, the depression connecting the holes, thereby forming through-holes.

According to another aspect, the present invention provides a filter plate for an inkjet head. The inkjet head includes a plurality of laminated plates including the filter plate. The plurality of laminated plates have holes that are arranged to form an ink channel. The filter plate is formed with a depression that is to be located in the ink channel when the plurality of plates are laminated together. A plurality of filter through-holes are formed through a bottom portion of the depression.

According to another aspect, the present invention provides an inkjet head including a plurality of laminated plates. The plates have holes that are arranged in communication with one another to form an ink channel. At least one of the plurality of plates is formed with a depression at a location in the ink channel. A plurality of filter through-holes are formed through a bottom of the depression.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become more apparent from reading the following description of the preferred embodiments taken in connection with the accompanying drawings in which:

FIG. 1 is an external perspective view of an ink-jet head according to a first embodiment of the present invention;

FIG. 2 is a cross-sectional view taken along a line II—II in FIG. 1;

FIG. 3 is an enlarged view of a region in FIG. 2 surrounded by a one-dot-and-one-chain line;

FIG. 4 is a plan view of a main head member shown in FIG. 1;

FIG. 5 is an enlarged plan view of a region in FIG. 4 surrounded by a one-dot-and-one-chain line;

FIG. 6(a) is a cross-sectional view taken along a line VI—VI in FIG. 5;

FIG. 6(b) is a plan view of an aperture shown in FIG. 6(a);

FIG. 7 is an exploded perspective view showing a portion of the main head member depicted in FIG. 5;

FIG. 8(a) is an enlarged cross-sectional view of a portion surrounded by a broken line in FIG. 6(a);

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FIG. 8(b) is a plan view of an individual electrode shown in FIG. 8(a);

FIG. 9(a) is a cross-sectional view of a reservoir unit taken along a line IX—IX in FIG. 1;

FIG. 9(b) is an enlarged cross-sectional view of a region in FIG. 9(a) surrounded by a broken line with alternating long and double short dashes;

FIG. 10 is an exploded view of the reservoir unit shown in FIG. 1;

FIGS. 11(a)–11(e) illustrate a process for manufacturing a filter in a third plate of the reservoir unit shown in FIG. 1, wherein FIG. 11(a) shows the third plate as the original plate material prior to forming the filter, FIG. 11(b) shows the third plate after resist layers have been formed over the surfaces thereof, FIG. 11(c) shows the third plate after holes are formed in the bottom surface and the resist layers are removed from the third plate subsequently, FIG. 11(d) shows the third plate after resist layers are again formed on the surfaces thereof, and FIG. 11(e) shows the completed filter formed in the third plate after a depression is formed and the resist layers are removed from the third plate subsequently; and

FIGS. 12(a) and 12(b) are cross-sectional views of the reservoir unit in an inkjet head according to a second embodiment of the present invention, wherein FIG. 12(a) is a cross-sectional view of the entire reservoir unit, and FIG. 12(b) is an enlarged cross-sectional view of a region in FIG. 12(a) surrounded by a broken line with alternating long and double short dashes.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An inkjet head according to preferred embodiments of the present invention will be described while referring to the accompanying drawings wherein like parts and components are designated by the same reference numerals to avoid duplicating description.

FIG. 1 is an external perspective view of an ink-jet head 1 according to a first embodiment of the present invention. FIG. 2 is a cross-sectional view taken along a line II—II in FIG. 1. FIG. 3 is an enlarged view of a region in FIG. 2 surrounded by a one-dot-and-one-chain line.

The inkjet head 1 includes: a main head member 70 having a flat rectangular shape extending in a main scanning direction and functioning to eject ink onto paper; a reservoir unit 71 disposed on the top surface of the main head member 70 and having an ink reservoir 3c (FIG. 9(a)) for accommodating ink to be supplied to the main head member 70; a controller 72 disposed above the reservoir unit 71 for controlling the main head member 70; and a lower cover 51 and an upper cover 52 for protecting the inkjet head 1 from sprayed ink. For the convenience of description, the upper cover 52 is omitted from FIG. 1, but is shown in FIG. 2. A sub-scanning direction is defined perpendicularly to the main scanning direction.

As shown in FIGS. 2 and 3, the main head member 70 includes: a channel unit 4 in which ink channels are formed; and a plurality of (four, in this embodiment) actuator units 21 bonded to the top surface of the channel unit 4 (FIG. 4). Each actuator unit 21 has a laminated structure in which a plurality of thin plates are stacked and bonded together as will be described with reference to FIG. 8.

As shown in FIG. 2, FIG. 9(a), and FIG. 10, the reservoir unit 71 is formed with a plurality of (ten, in this embodiment) upper ink supply channels 3d. The upper ink supply channels 3d extend downward and are opened on the bottom

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surface of the reservoir unit 71. As shown in FIG. 10, the upper ink supply channels 3d are located near both ends of the reservoir unit 71 with respect to the sub-scanning direction. The reservoir unit 71 contacts the channel unit 4 only at portions surrounding the openings of the upper ink supply channels 3d on the bottom surface of the reservoir unit 71. Accordingly, remaining regions of the reservoir unit 71 other than the portions surrounding the upper ink supply channels 3d are located separate from the main head member 70, forming a space 85. The actuator units 21 are disposed in the space 85.

A plurality of (four, in this embodiment) flexible printed circuits (FPCs) 50 are provided for supplying electricity to the plurality of (four, in this embodiment) actuator units 21, respectively. The FPCs 50 are electrically connected to the top surfaces of the actuator units 21, respectively. Two FPCs 50 are led away from one side of the channel unit 4 in the sub-scanning direction, while the other two FPCs 50 are led away from the other side of the channel unit 4 in the sub-scanning direction.

As shown in FIG. 1 and FIG. 9(a), the reservoir unit 71 includes: an ink inlet 3a and an ink downflow channel (reservoir channel) 3b. An ink supply connector 2 is attached to the ink inlet 3a. An ink tube (not shown) is connected to the ink supply connector 2. The ink downflow channel 3b has a downflow opening 63. Ink supplied from an ink tank (not shown) into the ink inlet 3a via the ink tube (not shown) and the ink supply connector 2 flows through the ink down-flow channel 3b, through the downflow opening 63, and accumulates in the ink reservoir 3c.

Ink accumulated in the ink reservoir 3c is supplied from the plurality of the upper ink supply channels 3d to a plurality of (ten, in this embodiment) lower ink supply channels 5d, which are formed in the channel unit 4 in one-to-one correspondence with the upper ink supply channels 3d as shown in FIG. 4. A manifold (common ink chamber) 5 is also formed in the channel unit 4 as shown in FIG. 4. The lower ink supply channels 5d are in fluid communication with the manifold 5.

As shown in FIG. 1, FIG. 3, and FIG. 10, a plurality of (four, in this embodiment) rectangular cutouts or recesses 53 are formed on the reservoir unit 71 in the thickness direction of the reservoir unit 71. The rectangular cutouts 53 are formed two on each side of the reservoir unit 71 with respect to the sub-scanning direction so that the rectangular cutouts 53 on opposing sides are staggered with respect to each other.

As shown in FIGS. 2, 3, and 10, the space 85 is in fluid communication with the rectangular cutouts 53. Each FPC 50 extends from the corresponding actuator unit 21, passes through the space 85, and passes through the corresponding rectangular cutout 53. As shown in FIGS. 1, 4, and 10, except for the rectangular cutouts 53, the reservoir unit 71 has essentially the same shape and dimensions in plan as the channel unit 4.

The controller 72 functions to control driving of the inkjet head 1. As shown in FIG. 1 and FIG. 2, the controller 72 includes: a main circuit board 72a; a plurality of (four, in this embodiment) sub-circuit boards 81; and a plurality of (four, in this embodiment) driver ICs 80.

The main circuit board 72a has a rectangular shape extending in the main scanning direction and is fixed on the reservoir unit 71 such that the surfaces opposing the sub-circuit boards 81 are perpendicular to the top surface of the reservoir unit 71. The sub-circuit boards 81 are disposed in

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parallel to the surfaces of the main circuit board **72a** and are electrically connected to the main circuit board **72a** via connectors **73**.

Each driver IC **80** functions to generate signals for driving a corresponding actuator unit **21**. Each driver IC **80** is provided with a heat sink **82**. Each driver IC **80** is fixedly mounted on a corresponding sub-circuit board **81** on its side that confronts the main circuit board **72a**.

Each FPC **50** is electrically connected to both of a corresponding sub-circuit board **81** and a corresponding driver IC **80**. Each FPC **50** is fixed to the sub-circuit boards **81** via adhesive **83**. Each FPC **50** is for transferring signals outputted from the sub-circuit board **81** to the driver IC **80**, and for transferring drive signals outputted from the driver IC **80** to the corresponding actuator unit **21**.

As shown in FIG. 3, each FPC **50** is bent and fixed by an adhesive **55** to the channel unit **4** at a location near an escape groove **54**, so that the FPC **50** does not come off of the corresponding actuator unit **21** when pulled upward.

As shown in FIGS. 1 and 2, the lower cover **51** is a substantially rectangular-shaped hollow case and has openings in the bottom and top thereof. The lower case **51** has essentially the same dimension in the sub-scanning direction in plan with the main head member **70** (reservoir unit **71** and channel unit **4**). In other words, the cross-section of the lower case **51** along a plane parallel to the top and bottom surfaces of the main head member **70** has the same dimension in the sub-scanning direction with the main head member **70**. As shown in FIG. 1, the lower cover **51** has a bottom edge **51b**. A plurality of (four, in this embodiment) protruding parts **51a** protrude downwardly from the bottom edge **51b**. The lower cover **51** is disposed on top of the main head body **70**. The bottom edge **51b** is located on the top surface of the reservoir unit **71**, while each protruding part **51a** is accommodated in a corresponding rectangular cutout **53** of the reservoir unit **71**. As shown in FIG. 2, each FPC **50** runs through a gap defined in the corresponding rectangular cutout **53**, and is drawn from the top of the reservoir unit **71**. The lower cover **51** covers the outer sides of portions of the FPCs **50** that extend along the rectangular cutouts **53** of the reservoir unit **71**.

As shown in FIG. 1, FIG. 2, and FIG. 3, each FPC **50** is accommodated in the lower cover **51** to extend loosely over the corresponding actuator unit **21** so as not to be applied with any stress. The bottom edge **51b** of the lower cover **51** is positioned on the upper edge of the reservoir unit **71**, while the protruding parts **51a** are positioned above the upper edge of the channel unit **4**.

As shown in FIG. 3, gaps **e** are formed between the protruding parts **51a** and the edge on the upper surface of the channel unit **4** for absorbing error in manufacturing the lower cover **51**. After the lower cover **51** has been mounted, the gaps **e** are filled with a silicone resin or the like to prevent ink from flowing out through the gaps **e**. The escape grooves **54** are formed in the channel unit **4** at positions opposing the rectangular cutouts **53** for allowing excess silicone to escape when filling the gaps **e** with silicone resin. As shown in FIGS. 1 and 2, the lower cover **51** further has a horizontal part **51d**, which surrounds the upper opening. The horizontal part **51d** is formed by bending the upper edges of the side wall of the lower cover **51** inward along the horizontal. The FPCs **50** are led through the top opening of the lower cover **51** that is surrounded by the planar part **51d**.

As shown in FIG. 2, the upper cover **52** is a casing with an arch-shaped ceiling, and is disposed on top of the horizontal parts **51d** of the lower cover **51** for covering the main circuit board **72a** and the sub-circuit boards **81**. When

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properly positioned, the lower cover **51** and upper cover **52** have a width in the sub-scanning direction that falls within the width of the main head member **70** in the sub-scanning direction.

Next, the structure of the main head member **70** will be described.

FIG. 4 is a plan view showing the main head member **70** of FIG. 1. FIG. 5 is an enlarged plan view showing the region in FIG. 4 surrounded by a one-dot-and-one-chain line. It is noted that for purposes of description, pressure chambers **10** (pressure chamber groups **9**), apertures **12**, and nozzles **8** (which will be described later) are depicted with solid lines in FIG. 5, although they are beneath the actuator units **21** and should be depicted in dotted lines. FIG. 6(a) is a cross-sectional view taken along a line VI—VI in FIG. 5. FIG. 6(b) is a plan view of an aperture **12** shown in FIG. 6(a). FIG. 7 is an exploded perspective view showing a part of the main head member **70**. FIG. 8(a) is an enlarged cross-sectional view of a part surrounded by a broken line in FIG. 6(a). FIG. 8(b) is a plan view showing the shape of an individual electrode **35** shown in FIG. 8(a).

As shown in FIGS. 4 and 5, the main head member **70** includes the channel unit **4**. A plurality of (four, in this embodiment) actuator units **21** are bonded to the top surface of the channel unit **4**. The actuator units **21** are disposed in a staggered arrangement of two rows on the top surface of the channel unit **4**. Each actuator unit **21** has a trapezoidal-shape cross-section along a plane parallel to the top and bottom surfaces of the actuator unit **21**. Each trapezoidal-shaped actuator unit **21** is positioned with its parallel sides (top and bottom sides of the trapezoid) aligned with the longitudinal direction (main scanning direction) of the channel unit **4**. The trapezoidal-shaped actuator units **21** are arranged on the top surface of the channel unit **4** so that the slanted sides (slanted sides of the trapezoids) of each two neighboring actuator units **21** confront with each other with a gap being formed therebetween.

A plurality of (four, in this embodiment) ink ejection regions **11** (FIG. 5) are defined on the bottom surface of the channel unit **4** in one-to-one correspondence with a plurality of (four, in this embodiment) regions of the top surface of the channel unit **4**, on which the plurality of (four, in this embodiment) actuator units **21** are bonded.

As shown in FIG. 5, numerous nozzles **8** are formed on the bottom surface of the channel unit **4** in each ink ejection region **11**. The nozzles **8** are arranged in a matrix form in the ink ejection region **11**. Numerous pressure chambers **10**, each of which is in fluid communication with a single nozzle **8**, are formed on the top surface of the channel unit **4** and are arranged also in a matrix. A single pressure chamber group **9** is configured of a plurality of the pressure chambers **10** that are disposed on the top surface of the channel unit **4** in correspondence with the area in which a single actuator unit **21** is bonded. In this way, the numerous pressure chambers **10** are grouped into a plurality of (four, in this embodiment) pressure chamber groups **9**. Each pressure chamber **10** has a substantially diamond-shaped cross-section along a plane parallel to the top and bottom surfaces of the chamber unit **4**.

As shown in FIG. 4, a manifold **5** is formed inside the channel unit **4**. The manifold **5** is configured from a plurality of sub-manifolds **5a**. A plurality of (ten, in this embodiment) openings **5b** are formed in the top surface of the channel unit **4** in fluid communication with the manifold **5**. More specifically, a lower ink supply channel **5d** extends from each opening **5b** to corresponding sub-manifolds **5a**.

As will be described with reference to FIG. 9(a) and FIG. 10, each opening 5b is joined with a corresponding upper ink supply channel 3d, which is opened on the bottom surface of the reservoir unit 71. Ink in the reservoir unit 71 is therefore supplied through the upper ink supply channels 3d to the lower ink supply channels 5d, and then to the sub-manifolds 5a.

As shown in FIG. 6(a), each nozzle 8 grows narrower toward its tip end. Each nozzle 8 is in fluid communication with a sub-manifold 5a via a corresponding pressure chamber 10 and a corresponding aperture 12. The sub-manifold 5a is a branch channel of the manifold 5.

Next, the cross-sectional structure of the main head member 70 will be described.

As shown in FIG. 6(a), each nozzle 8 is in fluid communication with a corresponding sub-manifold 5a via a corresponding pressure chamber 10 and a corresponding aperture 12. Accordingly, an individual ink channel 32 is formed in the main head member 70 for each pressure chamber 10 and extends from the outlet of the sub-manifold 5a to the nozzle 8 via the aperture 12 and the pressure chamber 10.

As shown in FIG. 7, the main head member 70 has a laminated structure that includes a total of ten stacked sheets. From top to bottom, these sheets include the actuator unit 21, a cavity plate 22, a base plate 23, an aperture plate 24, a supply plate 25, manifold plates 26, 27, and 28, a cover plate 29, and a nozzle plate 30. The channel unit 4 is configured of nine of these metal plates, excluding the actuator unit 21. These nine metal plates are formed of the same metal materials of stainless steel SUS316.

As will be described in detail later with reference to FIG. 8(a), the actuator unit 21 includes four laminated piezoelectric sheets 41–44, of which only the topmost sheet 41 has active layer portions (hereinafter referred to as the “active layer”) when an electric field is generated by electrodes, while the remaining three sheets 42–43 are inactive layers.

The cavity plate 22 is a metal plate provided with a plurality of substantially diamond-shaped openings (through-holes) defining the pressure chambers 10.

The base plate 23 is a metal plate. For each pressure chamber 10 in the cavity plate 22, the base plate 23 is formed with a communication through-hole connecting the pressure chamber 10 to a corresponding aperture 12 and another communication through-hole connecting the pressure chamber 10 to a corresponding nozzle 8.

The aperture plate 24 is a metal plate. For each pressure chamber 10 in the cavity plate 22, the aperture plate 24 is formed with a communication through-hole connecting the pressure chamber 10 to the nozzle 8. The aperture plate 24 is further formed with the aperture 12 for each pressure chamber 10 in the cavity plate 22. The aperture 12 penetrates through the aperture plate 24. As shown in FIG. 6(b), the aperture 12 has an elongated shape and includes: one circular-shaped end 12a that is in communication with the pressure chamber 10; the other circular-shaped end 12b that is in communication with the sub-manifold 5a; and a connecting section 12c that connects the circular-shaped ends 12a and 12b with each other. Each of the circular shaped ends 12a and 12b and the connecting section 12c penetrate through the aperture plate 24. Each of the circular-shaped ends 12a and 12b has a circular cross-section along a plane parallel to the top and bottom surfaces of the aperture plate 24. The connecting section 12c has an elongated cross-section along a plane parallel to the top and bottom surfaces of the aperture plate 24, and has a width smaller than the

diameters of the cross-section of the circular-shaped ends 12a and 12b. The aperture 12 is formed in the aperture plate 24 through an etching.

The supply plate 25 is a metal plate. For each pressure chamber 10 in the cavity plate 22, the supply plate 25 is provided with a communication through-hole connecting the aperture 12 and the sub-manifold 5a and a communication through-hole connecting the pressure chamber 10 with the nozzle 8.

The manifold plates 26, 27, and 28 are each provided with a through-hole for configuring the sub-manifold 5a when the plates are laminated together. For each pressure chamber 10 in the cavity plate 22, each plate 26, 27, and 28 is further formed with a communication through-hole connecting the pressure chamber 10 to the nozzle 8.

The cover plate 29 is a metal plate. For each pressure chamber 10 in the cavity plate 22, the cover plate 29 is provided with a communication through-hole connecting the pressure chamber 10 to the nozzle 8.

The nozzle plate 30 is a metal plate provided with the nozzle 8 for each pressure chamber 10 in the cavity plate 22.

These nine metal plates 22–30 are aligned and stacked together to form the ink channel 32 as shown in FIG. 6(a). The ink channel 32 begins from the sub-manifold 5a proceeding upward, extends horizontally in the aperture 12 before again proceeding upward, again extends horizontally in the pressure chamber 10, and then proceeds downward to the nozzle 8, first at a slant away from the aperture 12 and then straight downward.

Next, the structure of the actuator unit 21 will be described. The actuator unit 21 is stacked on the cavity plate 22, which is the topmost layer of the channel unit 4.

As shown in FIG. 8(a), the actuator unit 21 includes the four piezoelectric sheets 41–44, each having the same thickness of approximately 15 μm. These piezoelectric sheets 41–44 are continuous laminated plates (continuous planar layers) that span the plurality of pressure chambers 10 formed in a single ink ejection region 11 of the main head member 70 (FIG. 4 and FIG. 5). By disposing the piezoelectric sheets 41–44 as continuous planar layers over the plurality of pressure chambers 10, individual electrodes 35 can be densely arranged on the piezoelectric sheet 41 using a screen printing technique or the like. Therefore, the pressure chambers 10 can also be densely arranged at positions corresponding to the individual electrodes 35, enabling the printing of high-resolution images. The piezoelectric sheets 41–44 are formed of ferroelectric ceramics such as lead zirconate titanate (PZT).

The individual electrodes 35 are formed on top of the piezoelectric sheet 41, the topmost layer. The individual electrodes 35 are bonded to the top surface of the piezoelectric sheet 41. A common electrode 34 formed as a sheet with a uniform thickness of approximately 2 μm is interposed between the piezoelectric sheets 41 and 42. Electrodes are not provided between the piezoelectric sheets 42 and 43 and between the piezoelectric sheets 43 and 44. Both the individual electrodes 35 and the common electrode 34 are formed of a metal material such as Ag—Pd.

Each of the individual electrodes 35 is planar with a thickness of approximately 1 μm and is substantially diamond-shaped, as shown in FIG. 8(b), similar to the pressure chambers 10 shown in FIG. 5. A circular land 36 having a diameter of approximately 160 μm protrudes upwardly from one acute angle end of the individual electrode 35. The circular land 36 is electrically connected to the individual electrode 35. The land 36 is formed of gold including glass frit, for example. As shown in FIG. 8(a), the land 36 is

bonded to the surface of an extended part of the individual electrode 35. The land 36 is electrically joined to a contact provided on the FPC 50.

The common electrode 34 is electrically grounded in an area not shown in the drawing, enabling the common electrode 34 to be maintained equally at a ground potential for all areas corresponding to the pressure chambers 10. Further, the individual electrodes 35 are connected to the driver ICs 80 via the lands 36 and the FPCs 50, which include a plurality of independent lead wires for the plurality of individual electrodes 35 in order to independently control the potential of the individual electrodes 35 corresponding to the plurality of pressure chambers 10.

Next, a method of driving the actuator unit 21 will be described. The polarizing direction of the piezoelectric sheet 41 is equal to the direction of its thickness. Specifically, the actuator unit 21 has a unimorph structure in which the single piezoelectric sheet 41 on the top side (separated from the pressure chamber 10) serves as active layers, while the three piezoelectric sheets 42–44 on the bottom side (near the pressure chamber 10) are inactive layers. Accordingly, when a prescribed positive or negative potential is applied to individual electrodes 35 and if the directions of the electric field and polarization are the same, for example, areas of the piezoelectric sheet 41, which are interposed between the electrodes 35 and the common electrode 34 and at which an electric field is applied, function as active layers and compress in a direction orthogonal to the polarizing direction due to the transverse piezoelectric effect. The piezoelectric sheets 42–44 are not affected by the electric field and therefore do not spontaneously compress. Accordingly, a difference in strain between the piezoelectric sheet 41 and the piezoelectric sheets 42–44 is produced in the direction orthogonal to the polarizing direction, causing all of the piezoelectric sheets 41–44 to deform in a convex shape on the inactive side (unimorph deformation).

As shown in FIG. 8(a), since the bottom surface of the actuator unit 21 is fixed to the top surface of the cavity plate 22, which serves to partition the pressure chambers 10, the piezoelectric sheets 41–44 effectively deform in a convex shape toward the pressure chamber 10 side. As a result, the volumes of the pressure chambers 10 decrease, increasing the pressure of the ink and causing ink to eject from the nozzles 8. When the individual electrodes 35 are subsequently returned to the same potential as the common electrode 34, the piezoelectric sheets 41–44 return to their original shape and the pressure chambers 10 return to their original volumes, drawing ink in from the manifold 5 side.

Next, the structure of the reservoir unit 71 will be described in greater detail.

FIG. 9(a) and FIG. 9(b) are cross-sectional views of the reservoir unit 71 taken along a line IX—IX in FIG. 1. FIG. 9(a) is a cross-sectional view of the entire reservoir unit 71, while FIG. 9(b) is an enlarged cross-sectional view showing the region in FIG. 9(a) surrounded by a broken line having alternate long and double short dashes. FIG. 10 is an exploded view of the reservoir unit 71, with plan views of each plate constituting the reservoir unit 71. In FIG. 9(a) and FIG. 9(b), the scale of the drawings is exaggerated vertically for purposes of description.

As shown in FIG. 9(a), the reservoir unit 71 has a laminated structure including first through seventh plates 91–97. The plates 91–97 are rectangular in shape extending in the main scanning direction and are formed of the same metal materials of the metal plates 22–30 in the channel unit 4 described above.

When aligned and laminated, the plates 91–97 form the ink downflow channel 3b, the ink reservoir 3c, and the upper ink supply channels 3d in the reservoir unit 71. The ink inlet 3a is provided as an opening on the upstream side of the ink downflow channel 3b, while the downflow opening 63 is provided as another opening on the downstream side of the ink downflow channel 3b. The ink inlet 3a is positioned at the edge on the top surface of the reservoir unit 71, while the downflow opening 63 confronts the center of the ink reservoir 3c.

The ink reservoir 3c is in fluid communication with the ink downflow channel 3b via the downflow opening 63. The ink reservoir 3c is also in fluid communication with the ten upper ink supply channels 3d. Five upper ink supply channels 3d are arranged along the main scanning direction on each widthwise side of the reservoir unit 71. Since FIG. 9(a) is a cross-sectional view, only the five upper ink supply channels 3d and the five lower ink supply channels 5d formed on one widthwise side of the reservoir unit 71 are shown.

Next, each of the plates in the reservoir unit 71 will be described with reference to FIG. 10.

A total of four rectangular notches 53a are formed in both edges of the first plate 91 in the sub-scanning direction (a direction normal to the surface of FIG. 9(a)) with the two notches 53a in one edge staggered from the two notches 53a in the other edge in the main scanning direction. A circular through-hole 45 is formed in one end of the plate 91 with respect to the main scanning direction and near the center in the sub-scanning direction. The opening in the top of the through-hole 45 constitutes the ink inlet 3a.

A total of four rectangular notches 53b are formed in both edges of the second plate 92 with respect to the sub-scanning direction such that the two notches 53b in one edge are staggered from the two notches 53b in the other edge in the main scanning direction. As shown in FIG. 9(a), an elongated through-hole 46 is formed in the second plate 92 penetrating the same in the thickness direction and extends parallel to the main scanning direction from a position opposing the through-hole 45 to the center of the second plate 92 in the main scanning direction.

The third plate 93 (filter plate) is formed with no notches 53a or 53b, but has a width in the sub-scanning direction identical to the width of the first and second plates 91 and 92 in the sub-scanning direction between notches 53a and 53b, respectively. In other words, the third plate 93 has a width smaller than the width of the first plate 91 by an amount equal to twice the amount of the notch 53a. In other words, the third plate 93 has a width smaller than the width of the second plate 92 by an amount equal to twice the amount of the notch 53b. In this example, the third plate 93 has a width of about 22 mm in the sub-scanning direction, and a length of about 180 mm in the main scanning direction. The third plate 93 has a thickness of about 50 μm in this example.

As shown in FIG. 9(b) and FIG. 10, a recess 65 is formed in the third plate 93. A part of the plate 93, on which the recess 65 is formed, will be referred to as “bottom wall portion 65b” of the recess 65 hereinafter, and a remaining part of the plate 93, which is other than the bottom wall portion 65 and which surrounds the recess 65 in the main scanning direction and in the sub-scanning direction, will be referred to as “peripheral wall portion 65c”. The top surface of the peripheral wall portion 65c is attached to the second plate 92, while the bottom surface of the peripheral wall portion 65c is attached to the fourth plate 94. The bottom surface of the bottom wall portion 65b is on the same plane with the bottom surface of the peripheral wall portion 65c.

The top surface of the bottom wall portion **65b** is shifted in the thickness direction of the third plate **93** from the top surface of the peripheral wall portion **65c** by an amount of the depth of the recess **65**. In other words, the thickness of the bottom wall portion **65b** is less than the thickness of the peripheral wall portion **65c**, that is, the thickness of the third plate **93**. In this example, the depth of the recess **65** is about 47 μm . In other words, the thickness of the bottom wall portion **65b** is about 3 μm .

The recess **65** extends parallel to the main scanning direction from the center of the plate **93** toward the end corresponding to the through-hole **45**. The recess **65** has a width of about 10 mm in the sub-scanning direction, and a length of about 42 mm in the main scanning direction. In other words, the bottom wall portion **65b** extends parallel to the main scanning direction from the center of the plate **93** toward the end corresponding to the through-hole **45**. The bottom wall portion **65b** has a width of about 10 mm in the sub-scanning direction, and a length of about 42 mm in the main scanning direction.

A partitioning wall **65a** is disposed in the center of the recess **65** and extends in the sub-scanning direction. The partitioning wall **65a** protrudes upwardly in the thickness direction of the plate **93** from the bottom wall portion **65b**. The partitioning wall **65a** is connected to a pair of opposite sides of the peripheral wall portion **65c**, which confront with each other in the sub-scanning direction. The partitioning wall **65a** divides the recess **65** in two compartments. More specifically, the partitioning wall **65a** partitions the bottom wall portion **65b** into an upstream region **65u** and a downstream region **65d** with respect to a direction A, in which ink flows in the elongated through-hole **46** in the second plate **92** (upper ink downflow channel **64a**) as will be described later.

The height of the partitioning wall **65a** in the thickness direction of the plate **93** is substantially the same as the height of the peripheral wall portion **65c**. In other words, the top surface of the partitioning wall **65a** is on the same plane with the top surface of the peripheral wall portion **65c**. Accordingly, the partitioning wall **65a** can reinforce the bottom wall portion **65b** and suppress weakening of the plate **93**, thereby preventing damage to the filter **67**.

The shape of the partitioning wall **65a** in plan is not limited to that shown in FIG. **10**, but may be formed in other various shapes, such as a lattice shape, if the region of the recess **65** can be made appropriately large. Further, by connecting one or both ends of the partitioning wall **65a** to the peripheral wall portion **65c**, the reinforcing effect of the partitioning wall **65a** on the filter **67** is further enhanced.

A plurality of through-holes **66** is formed in rows in the main scanning direction in the bottom wall portion **65b**. In other words, the through-holes **66** are arranged in the main scanning direction. The bottom wall portion **65c**, which is located on a bottom of the recess **65** and which is formed with the through-holes **66**, constitutes a filter **67**. By providing a large recess **65** elongated in the main scanning direction in this way, the size of the filter **67** is large, and numerous through-holes **66** can be formed in the bottom of the recess **65**, thereby reducing the channel resistance on ink passing through the filter **67**.

It is noted that the through-holes **66** are formed in both of the upstream region **65u** and the downstream region **65d**. That is, at least one through-hole **66** is formed in each of the upstream region **65u** and the downstream region **65d**. In this embodiment, the total number of the through-holes **66** formed in the upstream region **65u** is the same as that of the through-holes **66** formed in the downstream region **65d**.

As shown in FIG. **9(b)**, each through-hole **66** has a circular cross-section along a plane parallel to the top and bottom surfaces of the third plate **93**. Each through-hole **66** is formed such that the surface area in the opening on the upstream end of the through-hole **66** with respect to a direction B, in which ink flows through the filter **67**, is smaller than that in the opening on the downstream end. In this example, the surface area in the opening on the upstream end of the through-holes **66** has a diameter of about 11 μm , while the surface area in the opening on the downstream end has a diameter of about 13 μm . It is noted that each nozzle **8** has a diameter of about 20 μm . By forming the opening in the downstream end of the through-hole **66** with a large surface area, the filtering effect of the through-hole **66** is the same as when the opening on the downstream end is formed smaller than that on the upstream end, but the flow resistance on ink passing through the through-hole **66** can be decreased. In other words, if the opening on the downstream end, or outlet, of the through-holes **66** is formed smaller than the opening on the upstream end, or inlet, ink can easily flow into the through-holes **66** but cannot easily flow out, thereby raising the flow resistance in the through-holes **66**. However, since the opening on the upstream end is made smaller than the opening on the downstream end in the present embodiment, ink flowing into the through-hole **66** through the opening on the upstream end can easily flow out through the opening on the downstream end, thereby reducing flow resistance.

A total of four rectangular notches **53c** are formed in the side edges of the fourth plate **94** with respect to the sub-scanning direction, wherein two of the notches **53c** formed in one edge are staggered from the two formed in the other edge in the main scanning direction. As shown in FIG. **9(a)** and FIG. **9(b)**, a through-hole **68** is formed in the plate **94** at a position opposing the filter **67** and penetrates the plate **94** in the thickness direction. As shown in FIG. **10**, the through-hole **68** is elongated in the main scanning direction.

A total of four rectangular notches **53d** are formed in the side edges of the fifth plate **95** with respect to the sub-scanning direction, wherein two of the notches **53d** formed in one edge are staggered from the two formed in the other edge in the main scanning direction. A circular through-hole **69** is formed in the center of the fifth plate **95** with respect to both the main scanning direction and the sub-scanning direction. The opening on the downstream end of the through-hole **69** constitutes the downflow opening **63**.

A total of four rectangular notches **53e** are formed in the side edges of the sixth plate **96** with respect to the sub-scanning direction, wherein two of the notches **53e** formed in one edge are staggered from the two formed in the other edge in the main scanning direction. A through-hole **31** is formed in the center of the plate **96** with respect to both the main scanning direction and the sub-scanning direction. The through-hole **31** constitutes the ink reservoir **3c**. The ink reservoir **3c** includes a main channel **37** and eight subsidiary channels **38**. The main channel **37** extends in the main scanning direction and tapers from the center of the ink reservoir **3c** toward two tip ends **3ce**, which are located near both ends of the plate **96** in the main scanning direction. The eight subsidiary channels **38** branch off the main channel **37** and taper toward eight tip ends **3ce**, which are located on both sides of the plate **96** in the sub-scanning direction. In this way, the ink reservoir **3c** has a plurality of (ten, in this embodiment) tip ends **3ce** at points corresponding to through-holes **33**, which are formed in the seventh plate **97** to constitute the plurality of (ten, in this embodiment) upper ink supply channels **3d** as will be described later.

A total of four rectangular notches **53f** are formed in the side edges of the seventh plate **97** with respect to the sub-scanning direction, wherein two of the notches **53f** formed in one edge are staggered from the two formed in the other edge in the main scanning direction.

The ten through-holes **33** are formed in the plate **97**. Each through-hole **33** constitutes the upper ink supply channel **3d**. Each through-hole **33** has a substantially circular cross-section along a plane parallel to the top and bottom surfaces of the seventh plate **87**. Five through-holes **33** are formed on each side of the plate **97** with respect to the sub-scanning direction, and are arranged along the main scanning direction. Further, the through-holes **33** formed in opposing sides of the plate **97** with respect to the sub-scanning direction are staggered in the main scanning direction by two units of two through-holes **33** and one unit of one through-hole **33** that is near an end of the plate **97** in the main scanning direction. The through-holes **33** are arranged symmetrically about a center point of the plate **97** with respect to the main scanning direction and the sub-scanning direction.

A recess **39** is formed by half etching in the surface of the plate **97** opposing the channel unit **4**. The outline of the recess **39** is indicated by broken lines in FIG. **10**. The recess **39** is opened at the both edges of the plate **97** in the sub-scanning direction at the notches **53f**. The recess **39** forms the space **85** described above when the plate **97** is stacked on the top surface of the channel unit **4**, as shown in FIG. **9(a)**.

When aligned, the notches **53a–53f** formed in the first, second, and fourth through seventh plates **91**, **92**, and **94–97** constitute the four rectangular cutouts **53** for leading out the four FPCs **50**, which are connected to the four actuator units **21**.

When a thermosetting adhesive is applied between each of the first through seventh plates **91–97** and the plates are bonded together by applying heat and pressure, the reservoir unit **71** configured of the plates **91–97** does not warp in a direction perpendicular to the top surface or bottom surface thereof, because the plates **91–97** are formed of the same metal materials. In other words, because the plates **91–97** are formed of the same metal materials, the linear expansion coefficients of the plates are equal to one another and hence each of the plates expands equally within the plane parallel to the top and bottom surfaces thereof when heat and pressure are applied. Accordingly, the reservoir unit **71** configured by joining the plates **91–97** with heat and pressure does not warp. Even if the third plate **93** shown in FIG. **9(a)** is formed of a different material than the other plates **91**, **92**, and **94–97** and therefore planar expansion of the plate **93** is different from those of the other plates, since the plate **93** is interposed between the second and fourth plates **92** and **94**, the reservoir unit **71** configured of the plates **91–97** exhibits almost no warp when the plates **91–97** are bonded by heat and pressure. It is noted, however, that when the plate **93** is formed of a different material than the other plates **91**, **92**, and **94–97**, it is desirable to select, for the plate **93**, a material whose linear expansion coefficient is similar to the linear expansion coefficients of the other plates **91**, **92**, and **94–97** as much as possible to deter warping in the reservoir unit **71**. In the present embodiment, both the channel unit **4** and the reservoir unit **71** are configured of metal plates to improve the durability of the inkjet head **1**.

Next, the ink channels in the reservoir unit **71** will be described.

Ink supplied from an ink tank (not shown) into the ink downflow channel **3b** via the ink inlet **3a** flows down into the ink reservoir **3c** through the downflow opening **63**. The filter

67 is disposed in the ink downflow channel **3b** as described above. The ink inlet **3a** is formed on one end of the reservoir unit **71** in the main scanning direction. The downflow opening **63** (circular through-hole **69**) is formed at a position opposing the center region of the ink reservoir **3c** that includes the center location among the plurality of upper ink supply channels **3d**. The filter **67** divides the ink downflow channel **3b** into an upper ink downflow channel **64a** formed above the filter **67** as a channel upstream of the filter **67**, and a lower ink downflow channel **64b** formed below the filter **67** as a channel downstream of the filter **67**. As shown in FIG. **9(a)**, the upper ink downflow channel **64a** is defined by a space provided by the through-hole **46**, while the lower ink downflow channel **64b** is defined by a space provided by the through-holes **68** and **69**. Hence, ink, which is supplied through the ink inlet **3a** provided on one end of the reservoir unit **71** in the main scanning direction, is guided through the ink downflow channel **3b** to flow into the downflow opening **63**, which is provided in the center of the reservoir unit **71** in the main scanning direction, thereby flowing into the center area of the ink reservoir **3c**.

Because the filter **67** is disposed in the ink downflow channel **3b**, the filter **67** has a large area and attains a small flow resistance on the ink being filtered. Specifically, since the cross-sectional area of the ink channel leading to the manifold **5** is greater than a microchannel such as the ink channel **32** in communication with the nozzle **8**, the filter **67** can be configured with a large surface area by being disposed in this ink channel.

The ink reservoir **3c** serves not only to store ink, but also to supply ink to the upper ink supply channels **3d**. The ink reservoir **3c** is in fluid communication with the upper ink supply channels **3d** at the ten tip ends **3ce**. These ten tip ends **3ce** are positioned in correspondence with the ten through-holes **33** constituting the upper ink supply channels **3d** formed in the plate **97** and are in fluid communication with the through-holes **33**. The ten tip ends **3ce** are arranged in two rows in the reservoir unit **71** along the main scanning direction, with five tip ends **3ce** located on each side of the reservoir unit **71** in the sub-scanning direction. The tip ends **3ce** on opposing sides are staggered in units of one formed near an end in the main scanning direction and the remainder in units of two. The ink reservoir **3c** has a cross-sectional shape, along a plane parallel to the top and bottom surfaces of the plate **96**, that is symmetrical about a center point of the plate **96** with respect to the main scanning direction, the center point being the point, at which ink flows from the downflow opening **63** into the ink reservoir **3c**.

The upper ink supply channels **3d** are in fluid communication with the ink reservoir **3c** on their upstream sides and are in fluid communication with the manifold **5** via the lower ink supply channels **5d** on their downstream sides. The upper ink supply channels **3d** receive ink from the ink reservoir **3c** and supply ink to the manifold **5**. The upper ink supply channels **3d** are formed in two rows along the main scanning direction, with five on each side of the reservoir unit **71** in the sub-scanning direction, and are located in one-to-one correspondence with the tip ends **3ce** of the ink reservoir **3c**. The upper ink supply channels **3d** on opposing sides of the reservoir unit **71** are staggered in units of two, except for one upper ink supply channel **3d** formed near both ends of the reservoir unit **71** in the main scanning direction. Hence, the upper ink supply channels **3d** are arranged symmetrically about a center point of the plate **97** with respect to the main scanning direction that corresponds to the point at which ink flows into the ink reservoir **3c** from the downflow opening **63**.

Next, the flow of ink in the reservoir unit 71 will be described.

Ink introduced into the ink inlet 3a of the reservoir unit 71 from an ink tank not shown in the drawings flows vertically (in the direction in which the plates 91–97 constituting the reservoir unit 71 are stacked) down into the ink downflow channel 3b. Ink that reaches the ink downflow channel 3b flows along the upper ink downflow channel 64a substantially in the main scanning direction and horizontally over the filter 67 (the direction along the planar surfaces of the plates 91–97), while being filtered through the filter 67. After passing through the filter 67, by which foreign matter is removed from the ink, the ink forms a vertical flow following the lower ink downflow channel 64b and flows down through the downflow opening 63 into the center region of the ink reservoir 3c. From the center region of the ink reservoir 3c, the ink flows toward both tip ends of the main channel 37 in the main scanning direction. A portion of ink reaches the tips 3ce at the ends of the main channel 37, and flows into the upper ink supply channels 3d. A remaining portion of the ink that flows through the main channel 37 flows into the plurality of sub-channels 38 branching off of the main channel 37. Ink reaching the end of these sub-channels 38 flows into the upper ink supply channels 3d. Ink introduced into the upper ink supply channels 3d flows through the upper ink supply channels 3d into the lower ink supply channels 5d of the channel unit 4 and is supplied to the manifold 5.

Next, a method of manufacturing the reservoir unit 71 will be described.

All of the plates 91–97 of the reservoir unit 71, excluding the third plate 93, are formed using an etching method well known in the art for producing the through-holes 31, 33, 45, and 69 and the elongated through-holes 46 and 48 in the plates 91, 92, and 94–97 and a punching process for forming the notches 53a–53f in the plates 91, 92, and 94–97. As described above, the recess 39 is formed in the bottom surface of the seventh plate 97 by half etching.

The filter 67 is formed in the third plate of the reservoir unit 71 according to the steps shown in FIG. 11(a)–FIG. 11(e).

FIG. 11(a) shows the plate material for the plate 93 prior to forming the filter 67. FIG. 11(b) shows the plate 93 after resist layers have been formed on the surfaces thereof. FIG. 11(c) shows the plate 93 after holes that will become the through-holes 66 have been formed in the bottom surface of the plate 93 and the resist layers have been removed. FIG. 11(d) shows the plate 93 after resist layers have again been formed over the surfaces of the plate 93. FIG. 11(e) shows the plate 93 after the recess 65 has been formed therein and the resist layers have been removed to complete formation of the filter 67.

In order to form the filter 67 in the plate 93, first, material for the plate 93 is prepared with no alterations, as shown in FIG. 11(a).

Then, resist layers 101 (101a and 101b) are formed on the top and bottom surfaces of the plate 93, as shown in FIG. 11(b). At this time, the resist layer 101a is formed over the entire top surface of the plate 93, while the resist layer 101b is formed over the bottom surface of the plate 93, excluding regions for forming the plurality of through-holes 66. After forming the resist layers 101 in this way, the plate 93 is immersed in a chemical solution that etches away areas of the plate 93 not covered by the resist layers 101 until semicircular depressions 66a have been formed, as shown in FIG. 11(c).

Subsequently, the resist layers 101 are removed from the plate 93, as shown in FIG. 11(c).

Next, other resist layers 102 are formed over the entire bottom surface of the plate 93 and over the top surface, excluding regions for forming the recess 65, as shown in FIG. 11(d). Hence, the top surface of the plate 93 is coated with the resist layer 102 so as to expose regions in which the plurality of depressions 66a have been formed and to cover all other areas (including the region in which the partitioning wall 65a is formed). After forming the resist layers 102, the plate 93 is immersed in a chemical solution that is allowed to etch away depressions in the plate 93 at areas not covered by the resist layers 102 (regions indicated by dotted lines in FIG. 11(d)) until the newly-created depressions reach the depressions 66a.

Subsequently, the resist layers 102 are removed from the plate 93, as shown in FIG. 11(e). In this way, it is possible to form in the plate 93 the plurality of through-holes 66, the recess 65 in fluid communication with the through-holes 66, and the partitioning wall 65a, thereby forming the filter 67 in the plate 93.

Hence, when forming the filter 67 in the plate 93, first, depressions 66a that will eventually become the through-holes 66 are formed in the bottom surface of the plate 93 by etching the bottom surface.

Next, the recess 65 and the partitioning wall 65a are formed by etching the top surface of the plate 93, simultaneously forming the through-holes 66 by connecting the bottom surface of the recess 65 with the depressions 66a.

Since the through-holes 66 of the filter 67 are formed from the bottom surface side of the plate 93 through the isotropic etching of a chemical solution, the area of the opening on the bottom surface side of the through-holes 66 in the thickness direction of the plate 93 is greater than the area of the opening on the top surface side. Accordingly, by disposing the plate 93 so that the upper surface side is the upstream side of the ink channel, the flow resistance to ink passing through the through-holes 66 is reduced, as described above.

Further, by forming the plurality of through-holes 66 in the bottom surface of the recess 65, it is possible to form through-holes 66 with small diameters and having a sufficient capacity for removing foreign matter, even when the plate 93 is relatively thick. Since the through-holes 66 can be formed with small diameters, a large number of the through-holes 66 can be formed densely within the region of the filter 67. Therefore, it is possible to use a thick plate 93 to facilitate handling when stacking the plate 93 with the other plates 91, 92, and 94–97, while also producing a filter 67 having numerous through-holes 66 with small diameters and an excellent filtering effect. This method also prevents an increase in flow resistance on ink passing through the filter 67 formed in the plate 93.

Further, the cost of manufacturing the third plate 93 having the filter 67 formed by etching can be much less than manufacturing a filter plate formed of a synthetic resin plate in which a plurality of through-holes have been formed with an excimer laser. Hence, the inkjet head 1 having this filter 67 can be manufactured at a low cost.

With the inkjet head 1 according to the embodiment described above, the filter 67 formed in the plate 93 of the reservoir unit 71 is configured of the recess 65 and the plurality of through-holes 66 formed in the bottom of the recess 65, enabling through-holes 66 with small diameters to be formed in a thick plate. Specifically, by providing the recess 65 in the plate 93, the bottom portion of the recess 65 in which the through-holes 66 are formed can be made extremely thin, reducing the amount of etching in the planar

direction of the plate 93 when forming the through-holes 66 by etching. As a result, the through-holes 66 can be formed with small diameters. Since a plurality of the through-holes 66 can be formed in the bottom of the recess 65, the flow resistance on ink passing through the filter 67 is reduced. Further, since a filter 67 having sufficient filtering capacity can be provided in a thick plate, the strength of the plate 93 in which the filter 67 is formed is not degraded, improving the handling of the plate 93 when laminating plates to form the reservoir unit 71.

While it is common to use a thinner plate for forming filter through-holes with a smaller diameter by etching, a thinner plate is not desirable when considering the handling strength of the plate. However, if a thicker plate is employed and etching is used to form through-holes from one surface side of the thick plate, the diameter of the through-holes grows in proportion to the thickness of the plate, because the etching proceeds isotropically.

Contrarily, according to the present embodiment, the filter 67 is formed in a thick plate with consideration for handling, and the through-holes 66 are formed in the bottom portion of the recess 65 formed in the plate. Therefore, a large number of small through-holes can be formed in the bottom of the recess, without being influenced by the thickness of the plate. Hence, the present embodiment can provide a plate that has the filter 67 having a sufficient filtering capacity and sufficient strength for handling, and that does not unduly increase flow resistance on the ink.

Next, an inkjet head according to a second embodiment of the present invention will be described.

FIG. 12(a) and FIG. 12(b) are cross-sectional views of the reservoir unit in an inkjet head according to the second embodiment, wherein FIG. 12(a) is a cross-sectional view showing the entire reservoir unit, while FIG. 12(b) is an enlarged cross-sectional view of the region in FIG. 12(a) surrounded by a broken line with alternating long and double short dashes. For purposes of description, the vertical dimension of the reservoir unit in FIG. 12(a) and FIG. 12(b) is exaggerated. Parts and components similar to those of the inkjet head 1 according to the first embodiment described above are indicated by the same reference numerals to avoid duplicating description.

An inkjet head 201 according to the second embodiment includes a reservoir unit 271 shown in FIG. 12(a). The reservoir unit 271 has the same construction as the reservoir unit 71 according to the first embodiment described above, except that a third plate 93' is used instead of the third plate 93 of the first embodiment and that the third plate 93' has a filter 267 instead of the filter 67 in the first embodiment.

The filter 267 includes: the bottom wall portion 65b defining the recess 65 thereon; a plurality of through-holes 266 and a plurality of through-holes 268, both of which are formed in the bottom wall portion 65b; and the partitioning wall 65a. As shown in FIG. 12(b), the partitioning wall 65a partitions the bottom wall portion 65b into the upstream region 65u and the downstream region 65d with respect to the direction A, in which ink flows in the upper ink downflow channel 64a. The through-holes 266 are formed in the upstream region 65u, while the through-holes 268 are formed in the downstream region 65d. The total number of the through-holes 266 is the same as that of the through-holes 268. Each of the through-holes 266 and 268 is shaped similar to the through-hole 66 in the first embodiment. More specifically, the area of the opening of each through-hole 266 in the bottom surface side of the third plate 93' is greater than the area of the opening of the through-hole 266 on the top surface side, and the area of the opening of each

through-hole 267 in the bottom surface side of the third plate 93' is greater than the area of the opening of the through-hole 267 on the top surface side. According to the present embodiment, however, each through-hole 266 is formed with a smaller diameter than each through-hole 268. For example, the diameter of each through-holes 266 is smaller than that of the through-hole 268 by an amount of about 2 μm .

The method of forming the filter 267 in the third plate 93' according to the present embodiment is substantially the same as the method of forming the filter 67 in the plate 93 according to the first embodiment. However, when forming the areas of the through-holes 266 and 268 by etching, the resist layer is formed on the third plate 93' at regions corresponding to the through-holes 266 and 268 having different diameters. Hence, the resist layer is formed at different regions than the resist layer 101b in the first embodiment described above. Otherwise, the method of forming the filter 267 in the third plate 93' is identical to the method of forming the filter 67 in the first embodiment.

In addition to the advantages obtained by the ink-jet head 1 according to the first embodiment described above, the inkjet head 201 according to the second embodiment obtains the following advantages.

By forming the diameter of the through-holes 268 in the filter 267 larger than that of the through-holes 266, the through-holes 268 have less pressure loss than the through-holes 266. For this reason, ink flowing through the through-holes 268 has less flow resistance, facilitating the flow of ink in the downstream region of the upper ink downflow channel 64a and preventing bubbles from accumulating in the ink in the area of the upper ink downflow channel 64a that confronts the through-holes 268. More specifically, since the ink downflow channel 3b changes the ink flow from a horizontal direction A in the upper ink downflow channel 64a to a vertical direction B in the lower ink downflow channel 64b, the flow of ink tends to stagnate in a corner P shown in FIG. 12(a) in the downstream region of the upper ink downflow channel 64a, and air bubbles in the ink tend to accumulate at this corner P. However, in the present embodiment, ink flows more freely through the through-holes 268 provided near the corner P in the downstream region of the upper ink downflow channel 64a, thereby preventing air bubbles from accumulating in the corner P.

In the inkjet head 1 of the first embodiment described above, the number of the through-holes 66 formed in the upstream region 65u is equal to the number of the through-holes 66 formed in the downstream region 65d, and all of the through-holes 66 have the same diameter. However, the number of through-holes 66 in the upstream region 65u may be made smaller than the number in the downstream region 65d in order to produce a differential in pressure loss between the upstream side and downstream side of the upper ink downflow channel 64a, thereby reducing the pressure loss of ink passing through the through-holes 66 formed in the downstream region 65d. Hence, the flow resistance on ink passing through the through-holes 66 formed in the downstream region 65d can be made less than the flow resistance on ink passing through through-holes 66 formed in the upstream region 65u, thereby facilitating the flow of ink through the downstream region of the upper ink downflow channel 64a so that air bubbles in the ink have less tendency to accumulate in the corner P of the downstream region.

While the invention has been described in detail with reference to the specific embodiments thereof, it would be

apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention.

For example, the filter may be formed in the individual ink channels in the channel unit **4**. For example, the filter may be formed at a location between the lower ink supply channel **5d** and the sub-manifold **5a**.

The partitioning wall **65a** may be eliminated from the filter **67** and the filter **267**.

The openings in the top surface side of the through-holes **66** formed in the filter **67** may be larger than the openings in the downstream end. That is, when forming the filter **67**, the recess **65** may be formed first, and the through-holes **66** may be subsequently formed in the thin bottom portion of the recess **65** from the recess **65** side.

Further, in the preferred embodiments, the partitioning wall **65a** is formed in the ink downflow channel **3b** to extend in the sub-scanning direction (orthogonal to the direction A of ink flow), but may be formed to extend in the main scanning direction (the direction A of ink flow). This construction can produce a smooth flow of ink through the upper ink downflow channel **64a**. In this case, it is desirable that the downstream end of the partitioning wall **65a** be connected to the peripheral wall portion **65c**. This construction serves not only as a structural reinforcement of the filter **67** or filter **267**, but also to guide air bubbles in the ink to the downstream side of the upper ink downflow channel **64a**. Especially in a filter constructed like the filter **267** of the second embodiment to facilitate ink flow in the downstream region of the filter **267**, air bubbles in the ink can be easily discharged rather than being accumulated.

Further, the method for forming the filter **67** in the plate **93** is not limited to an etching method. The present invention may be applied to any method for forming filter through-holes by removing plate material isotropically from one surface side of the plate.

What is claimed is:

1. An inkjet head, comprising:

a plurality of laminated plates, the plates having holes that are arranged in communication with one another to form an ink channel,

at least one of the plurality of plates including a filter portion disposed in the ink channel, the filter portion including a bottom wall portion defining a depression thereon, a plurality of filter through-holes being formed through the bottom wall portion, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

2. The inkjet head according to claim **1**, wherein the at least one plate includes a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface.

3. The inkjet head according to claim **1**, wherein the at least one plate includes a peripheral wall portion, the depression being surrounded by the bottom wall portion and the peripheral wall portion, the peripheral wall portion having a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom

surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface.

4. The inkjet head according to claim **3**, wherein the second surface is located on the same plane with the second bottom surface, and wherein the first bottom surface is shifted from the first surface by a depth of the depression, the depth of the depression being equal to a difference between the plate thickness and the bottom thickness.

5. The inkjet head according to claim **1**, wherein the plurality of plates include an ink-inlet plate formed with an ink inlet,

further comprising:

a nozzle plate formed with a plurality of nozzles; and another plurality of laminated plates formed with a common ink chamber that is in fluid communication with the ink channel and that is in fluid communication with the plurality of nozzles, the ink channel being configured so that ink supplied from an external source through the ink inlet flows through the common ink chamber toward the plurality of nozzles to be ejected.

6. The inkjet head according to claim **5**, wherein the filter portion is disposed in the ink channel between the ink inlet and the common ink chamber.

7. The inkjet head according to claim **6**, wherein the ink channel includes an ink reservoir that stores ink therein, the ink reservoir being disposed between the ink inlet and the common ink chamber; and

the filter portion is disposed in a reservoir channel defined between the ink inlet and the ink reservoir.

8. The inkjet head according to claim **7**, wherein the plurality of filter through-holes in the filter portion include: an upstream-side filter through-hole; and

a downstream-side filter through-hole that is located in a downstream side of the upstream-side filter through-hole in the ink flowing direction along the reservoir channel,

the upstream-side filter through-hole having a smaller diameter than the downstream-side filter through-hole.

9. The inkjet head according to claim **1**, wherein the at least one plate is elongated in a predetermined direction, the depression being elongated in the predetermined direction, and the plurality of filter through-holes are arranged along the predetermined direction.

10. The inkjet head according to claim **1**, wherein the filter portion has a partitioning wall that divides the depression into a plurality of compartments, each compartment including at least one filter through-hole.

11. The inkjet head according to claim **10**, wherein both ends of the partitioning wall connect to peripheral wall portions of the depression, and the thickness of the plate is greater than the thickness of the bottom wall portion of the depression.

12. The inkjet head according to claim **1**, wherein each of the plurality of plates is a metal plate.

13. The inkjet head according to claim **1**, further comprising a channel unit in which a plurality of nozzles and a plurality of pressure chambers are formed,

wherein the plurality of laminated plates configure a reservoir unit fixed to the channel unit,

the reservoir unit including in the ink channel:

an ink inlet;

an ink reservoir;

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a reservoir channel connecting the ink reservoir to the ink inlet, the filter portion being disposed in the reservoir channel; and
 a plurality of first ink supply channels communicating outside of the reservoir unit with the ink reservoir, the channel unit including:
 a common ink chamber;
 a plurality of individual ink channels extending from an outlet of the common ink chamber through the plurality of pressure chambers to the plurality of nozzles; and
 a plurality of second ink supply channels in fluid communication with the corresponding first ink supply channels to connect the ink reservoir to the common ink chamber.

14. The inkjet head according to claim **13**, wherein the channel unit is configured of another plurality of laminated plates having holes for forming the nozzles, the pressure chambers, the common ink chamber, the individual ink channels, and the plurality of second ink supply channels, and wherein each plate in the channel unit is a metal plate and each plate in the reservoir unit is a metal plate.

15. The inkjet head according to claim **14**, wherein the plurality of filter through-holes are formed by etching one surface side of the metal plate, and the depression is formed by etching the opposite surface of the metal plate.

16. The inkjet head according to claim **15**, wherein the metal plate having the filter portion is formed of the same metal material as the other metal plates constituting the channel unit and the reservoir unit.

17. A filter plate for an inkjet head, the inkjet head including a plurality of laminated plates, the plurality of plates including the filter plate, the plurality of laminated plates having holes that are arranged to form an ink channel, the filter plate comprising:

a filter portion, which is disposed in the ink channel which is formed when the plurality of plates are laminated together, the filter portion including a bottom wall portion defining a depression thereon, a plurality of filter through-holes being formed through the bottom wall portion, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

18. The filter plate according to claim **17**, further comprising a peripheral wall portion, the depression being surrounded by the bottom wall portion and the peripheral wall portion, the peripheral wall portion having a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface,

the second surface being located on the same plane with the second bottom surface, and the first bottom surface being shifted from the first surface by a depth of the depression, the depth of the depression being equal to a difference between the plate thickness and the bottom thickness.

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19. A method of manufacturing a filter plate serving as a component of an inkjet head including a plurality of laminated plates, the plates having holes that are arranged to form an ink channel, the filter plate having a filter portion that traps foreign matter in ink in the ink channel, the method comprising:

forming a plurality of holes within a predetermined region on one surface of a metal plate, the holes having a depth smaller than the thickness of the metal plate; and

forming filter through-holes penetrating the metal plate by etching a depression across the entire predetermined region on the opposite surface of the metal plate, the depression connecting the holes, thereby forming through-holes.

20. The method of manufacturing a filter plate according to claim **19**, wherein the hole forming step includes:

forming a resist layer on the one surface of the metal plate, while exposing hole forming regions desired to form the plurality of holes, and forming another resist layer over the entire surface of at least the predetermined region on the opposite surface of the metal plate;

forming the plurality of holes by etching the hole forming regions; and

removing the resist layers from the metal plate.

21. The method of manufacturing a filter plate according to claim **19**, wherein the depression forming step includes:

forming a resist layer over the entire surface of at least the predetermined region on the one surface of the metal plate and forming a resist layer on the opposite surface while exposing the predetermined region;

forming the depression by etching the predetermined region; and

removing the resist layers from the metal plate.

22. A filter plate for an inkjet head, the inkjet head including a plurality of laminated plates including the filter plate, the plurality of laminated plates having holes that are arranged to form an ink channel, the filter plate being formed with a depression that is to be located in the ink channel when the plurality of plates are laminated together, a plurality of filter through-holes being formed through a bottom portion of the depression, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

23. An inkjet head, comprising:

a plurality of laminated plates, the plates having holes that are arranged in communication with one another to form an ink channel, at least one of the plurality of plates being formed with a depression at a location in the ink channel, a plurality of filter through-holes being formed through a bottom of the depression, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.